FIRST BOOKS OF SCIENCE

A FIRST BOOK OF BOTANY

MACMILLAN AND CO., Limited
LONDON · BOMBAY · CALCUTTA · MADRAS
MELBOURNE

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO
DALLAS · SAN FRANCISCO

THE MACMILLAN CO. OF CANADA, Ltd.
TORONTO

A FIRST BOOK OF BOTANY

ELIZABETH HEALEY

ASSOCIATE OF THE ROYAL COLLEGE OF SCIENCE, LONDON
ASSISTANT LECTURER IN THE UNIVERSITY COLLEGE
OF SOUTH WALES AND MONMOUTHSHIRE

MACMILLAN AND CO., LIMITED
ST. MARTIN'S STREET, LONDON

1917

First Edition April 1909.
Reprinted October 1909, 1911, 1913, 1915, 1917.

GLASGOW: PRINTED AT THE UNIVERSITY PRESS
BY ROBERT MACLEHOSE AND CO. LTD.

PREFACE.

THE school year now usually begins in September, and for this reason the course of work in this little book has been planned to follow so far as possible a seasonal arrangement, with a study of fruits as a starting point.

Though a bird's-eye view of the subject is presented, the intention throughout has been to provide work only on the elementary facts and principles of the science.

Observation and experiment are the dominating notes of the lessons, and from the beginning great stress is laid on the need for constant practice in accurate sketching from actual plant specimens. Typical questions have been included in order that the power of writing clear, simple accounts, in well-chosen words, of all observations and experiments made may be encouraged. The need for precise accounts of what has been done by the pupil has also been remembered in drawing up the instructions for practical work.

Great care has been taken to ensure that the illustrations should be accurate and artistic.

Most of the specimens required for examination are such as can be obtained easily, and the amount of apparatus required has been reduced to a minimum.

Permission to include questions set in examinations of the Board of Education, Cambridge Local Examination

Syndicate, and the National Froebel Union is acknowledged gratefully.

Hearty thanks are offered to many friends for aid, advice, and encouragement during the preparation of the book: to Mr. A. T. Simmons for his unfailing patience and helpful kindness; to Miss E. d'Auvergne of Penarth County School, Prof. R. A. Gregory and Prof. H. Bruce for valuable suggestions and criticisms; and to Mrs. Alfred Harris, Miss Ethel Healey, and Mr. F. G. Sanders for many of the photographs and drawings specially made to illustrate this book.

ELIZABETH HEALEY.

CARDIFF,
March, 1909.

CONTENTS.

CONTENTS

CHAPTER I.

THE BUTTERCUP.

The buttercup plant.—In open meadows from early summer to autumn there are sure to be buttercups in flower. It is not easy to pull one up; the whole plant can only be got out of the ground uninjured by careful digging. The difficulty of pulling up the root shows very quickly one use of that part of the buttercup. It keeps the plant fixed firmly in the ground and prevents it from being dragged out by the pressure of the wind, or by the weight of its own leaves and flowers.

FIG. 1.—An uprooted buttercup.

The **root** consists of a number of string-like fibres, which have thinner branches, and to them grains of the soil cling firmly; some of the earth can be washed off if the root be put in water. If a dandelion root be compared with that of a buttercup, it is seen to be a thick single root which goes straight down and finally has small branches; but it does not spread like the buttercup root. In neither case is it easy to pull up the whole plant.

CHAPTER II.

FRUITS.

The seasons.—The seasons of the year pass gradually into each other; it is not possible to say on any particular day, "Spring weather ends to-day, to-morrow will be the first day of summer weather." So, in the world of plants, seasonal changes take place slowly, and the various stages blend insensibly into each other. There are some flowers even in mid-winter; and green-leaved plants are to be found in sheltered places all the year round. Roughly, however, the seasons may be said to be four in number.

Spring is the time of budding trees, growing seedlings and opening leaves; summer is mainly the time of blossoms; autumn consists of the months of fruits, seeds, and falling leaves; and winter of those of rest and unseen preparation for the renewal of vigorous growth in spring.

September is a transition month between summer and autumn. There are still many flowers in field, lane, and garden, but the leaves of most trees are beginning to change from green to brown, red, or gold; the hedges are bright with scarlet and yellow berries and the white feathery trails of "traveller's joy." It is therefore a good time of year in which to study different kinds of fruits and to notice how they help in dispersing seeds.

Fruits.—The fruit is that part of the flower which remains after the coloured petals have fallen off, and the

stamens have dropped or withered. It contains the seeds, and is usually small and green while in the flower, but afterwards it grows much bigger and often alters in colour. This change is called the *ripening* of the fruit. The calyx often remains attached to the fruit.

FIG. 4.—Fruit of field poppy.

There are several ways in which fruits may be divided into classes or classified. One way is according to what the outside of the fruit is like. If it is dry, or hard, it is called a **dry** fruit; and those fruits which are juicy and fleshy outside the seed are called **succulent,** which means juicy. Examples of dry fruits are the ripened pods of peas, beans, and laburnum, and the nuts of hazels and acorns; while the orange, apple, grape, and banana are succulent fruits.

Another way of classifying fruits is to notice whether they split open, and whether the seed drops out when the fruit is ripe in autumn. Such fruits are called **splitting** or **dehiscent** fruits. Those fruits which after dropping off the parent plant still contain their seeds are called **indehiscent** or **non-splitting** fruits.

Classification of fruits.—The following arrangement is best to follow at first:

1. Capsular or Box-like fruits.—In these fruits the seeds are contained in a dry case which opens and lets the seeds fall out when the fruit is ripe.

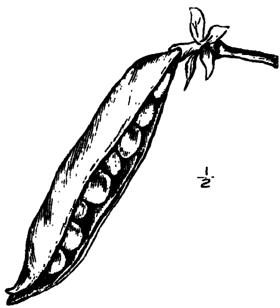


FIG. 5.—Pod of pea.

In the poppy, the fruit is a round *capsule* with a flat top, and just below the top is a row of holes. On a windy day

the poppy head swings backwards and forwards, and the little seeds fall to the ground through the holes (Fig. 4).

In the pea, the *pod* opens along its edges, and the seeds drop out through the opening (Fig. 5). Other examples

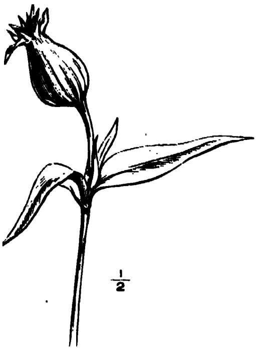


FIG. 6.—Fruit of campion opening by teeth.

FIG. 7.—Fruit of hogweed.

of box-fruits are found in the laburnum, violet, pansy, columbine, lupin, mignonette, peony, gorse, wall-flower, campion. In the campion, the fruit opens by teeth (Fig. 6).

2. **Dividing fruits.**—These fruits when ripe separate into compartments, each containing one seed. Examples of this class are the fruits of hogweed (Fig. 7), dead nettle, mallow, and sycamore (Fig. 8).

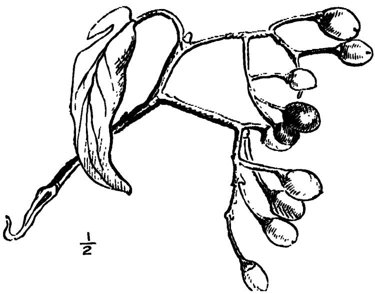
FIG. 8.—Fruits of sycamore.

3. **Nuts and nutlets.**—These fruits have a hard shell or tough husk, and contain only one seed. To this class belong the hazel, acorn, dandelion, elm, wheat, oat, thistle, and grass.

4. **Stone fruits** have usually a brightly coloured skin, inside which is a fleshy pulp often sweet in taste; and the

seed is enclosed in a hard stony case. The skin, pulp, and stony case form the parts of the fruit. The kernel of the stone is the seed. Cherries, plums, peaches, apricots, and nectarines are well known stone fruits.

5. **Berries.**—These fruits have an outer skin, sometimes tough and thick, and when ripe contain a soft pulp in which are several hard seeds. Grapes, tomatoes, gooseberries, oranges, lemons, vegetable marrows, and cucumbers all belong to the class of berries. The date is a one-seeded berry.



1/2

Fig. 9.—Berries of woody nightshade.

Some wild berries are the woody nightshade or bitter-sweet (Fig. 9), bryony, and wild arum.

6. **Other fruits.**—There are some fruits which are not included in any of these five classes because they are not formed from the ripened pistil alone; in these, other parts of the flower have joined to the carpels and so become part of the fruit.

In the apple and pear the fruit is formed from the enlarged top of the flower stalk on which the parts of the flower grew. The withered remains of the flower may be seen on the parts of the apple or pear opposite to the stalk. It is easier to make out in the pear than in the apple that the outer part of the fruit is really the expanded and swollen top of the flower stalk. The passage from stalk to fruit can be easily traced in many pears.

In the strawberry the top of the flower stalk becomes much swollen and brightly coloured; and the seeds are carried in small dry true fruits, the ripened pistils, which form the dark spots on the strawberry.

In the apple the swollen flower stalk is hollow inside and the seeds are enclosed; in the strawberry it is solid, and the true fruits rest on the round outer surface.

The blackberry and raspberry each consist of a number of small stone-fruits on the swollen end of the flower stalk. They do not belong to the botanical class of berries.

PRACTICAL WORK.

Collect, draw, and examine different kinds of fruits.

The dry fruits may be mounted on sheets of cardboard and preserved for reference during the term. All seeds should be kept until the time for sowing them comes.

Arrange the fruits in classes according to the five sections described in this chapter.

Make notes of any special characteristics, such as the wings of the fruits of ash, sycamore, maple, elm; the cup of the acorn; the outer coverings of the hazel, chestnut, and beech.

Make drawings of the following fruits, and observe carefully their structure: the apple, pear, wild strawberry (probably to be found in most country places in September), and blackberry.

CHAPTER III.

THE DISPERSAL OF FRUITS.

Uses of fruits.—One use of the fruit to the plant is to cover up the young seeds and so protect them from injury. When the fruit is ripe it helps to secure the scattering of the seed in places where it will grow well.

How seeds are scattered.—There are several ways in which the scattering of seeds takes place.

FIG. 10.—Fruit of ash.

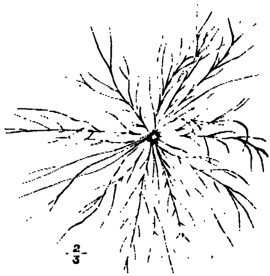


FIG. 11.—Plumed fruit of thistle.

1. Dispersal by the wind.—Fruits carried by the wind have special arrangements which make scattering easy:

(*a*) Some fruits are *flattened* in shape, for example, the divided parts of the hogweed fruit (Fig. 7).

(*b*) Some have *wings* as the elm, ash, and sycamore (Fig. 8).

(*c*) Some have *tufts of hair* which act as a parachute or flying machine. Examples: dandelion, thistle (Fig. 11), clematis.

When seeds are very small they are blown about freely by the wind after being set free from the fruit. This happens in the orchid, which has a box fruit and very small seeds which can be carried a long distance by the wind because they are very light.

When the seeds are larger, the fruit often opens in such a way that the seeds can only be jerked out by a high wind; this is the case with the poppy, monkshood, and pink.

The willow, poplar, and willow-herb have seeds bearing a tuft of hair; so here the seeds, not the fruits, are dispersed by the wind (Fig. 12).

FIG. 12.—Fruit of willow-herb before and after opening.

Usually it is large trees which have winged fruits or seeds. As they settle slowly the fruits are carried some distance before they reach the ground. They need a strong wind to detach them from the tree. The small fruits with tufts of hair are very light and travel a long way before they fall to earth. They are separated from the plant by slight winds.

2. **Seeds scattered by explosive fruits.**—The violet has a box-like fruit which opens into three parts; these parts dry and pinch the seeds so that they are sent a considerable distance from the parent plant (Figs. 13 and 14).

In Herb Robert the seeds are thrown out with a jerk.

Other fruits which scatter their seeds in a similar way are the gorse (the pods of which may be heard and seen exploding on any common in August and September), balsam, or touch-me-not, and the squirting cucumber. The last-named plant is a small cucumber grown sometimes in

greenhouses in England. When ripe it is full of a thick liquid containing the seeds, and if touched when nearly ready

FIG. 13.—Fruit of violet before opening.

FIG. 14.—Fruit of violet, open.

to burst automatically, it throws the fluid a great distance; anyone who is near may receive a violent blow on the face.

FIG. 15.—Fruit of wood avens.

3. Fruits dispersed by clinging to or being transported inside animals.—Many fruits have small hooks on their surface, which cause them to stick to the fur or wool of animals that pass by. These fruits are found very often on hedge and woodland plants, such as goose-grass or "cleavers," wood avens (Fig. 15), forget-me-not.

The "Queensland upas tree" has very sticky fruits which cling to the feathers of birds.

Fruits which have a brightly coloured skin and

sweet pulp are attractive to animals, which eat them, and in so doing often throw the seed away. When the seed is swallowed, its hard outside protects it from being digested and it is dropped unhurt after passing through the animal. Examples of such fruits are cherries, mistletoe, holly, hips and haws, bryony, currants, apples, plums, peaches and apricots.

Fruits which depend on birds for their dispersal are commonly brightly coloured, usually red or yellow, or they may be black or white. The white berries of the mistletoe are eaten chiefly by thrushes; the missel thrush was so named because it was supposed to feed mainly on mistletoe.

In stone fruits the hard inner layer of the fruit protects the seed effectively until the time comes for the seed to begin to grow. The stone has then usually been lying on the ground for some time and the outer part has decayed, so that the growing parts of the seed can force their way out, as will be described in the next chapter. The peach has a very hard, furrowed stone, which probably in its native land protected it against the sharp teeth of monkeys and large fruit-eating animals, as it comes from China and other parts of Asia. From the Latin name which meant the fruit of the Persian tree, the English word peach is derived. The seeds of stone fruits are often bitter and unpleasant in taste.

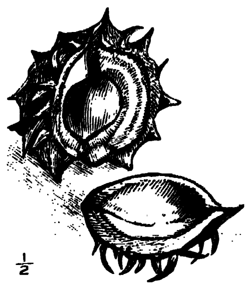


FIG. 16.—Fruit of horse chestnut, showing outside and seed.

When seeds themselves are pleasant to eat they are protected by a thick, untempting, often bitter, case. Such are found in the Spanish chestnut, beech, walnut, and almond. Squirrels store these seeds for food, but often forget their hiding places, and the nuts then grow up into new trees.

4. Fruits dispersed by water.—Many fruits and seeds of plants growing near water will float for a long distance and will grow after being in sea or fresh water for several days; some have been known to float for as long as 143 days. These fruits usually have special contrivances to enable them to float; sometimes this is a floating water-tight bladder containing air; more often it is a floating tissue in a thick husk, as for example, the cocoa-nut.

In this way plants may be carried from one continent or country to another far distant.

The great Swedish botanist Linnaeus found on the coast of Norway seeds and fruits from the West Indies, evidently carried across the Atlantic Ocean by ocean currents. Another botanist (Schimper) says of the fruits and seeds thrown up on the coast of Java: "Many of them come from plants that one might look in vain for in the neighbourhood. . . . Many of the fruits look nearly as fresh as if they had just fallen from the tree, . . . others bear traces of a long journey; their husks perforated like a sieve; many, hollowed out by animals. . . . In most cases even when the fruits are much worn, the seeds are quite sound."

PRACTICAL WORK.

Study again the fruits already collected, and arrange them in classes according to the manner in which their seeds are scattered.

Draw and examine carefully the *seeds* of willow herb, and the *fruits* of clematis, dandelion, and hemlock.

Try to procure unopened fruits of dog-violet, broom, balsam, and wood-sorrel. Find out and describe the method by which the seeds are ejected.

Take the first opportunity to notice the strong wind required to detach winged fruits from forest trees. Try for yourself that a gentle puff will loosen the feathery fruits of dandelion, thistle, and clematis.

CHAPTER IV.

SEEDS AND GERMINATION.

In studying the parts of a plant it is usual to begin with a full-grown plant, as was done in the case of the buttercup in Chapter I.; but to study it alive and to find out the ways in which it feeds and grows, it is necessary to watch the plant from the time when it is a seed. The life of plants is of very great importance, since all animals depend directly or indirectly on plants for food. The various changes through which a plant passes from the time of being a seed until it produces flowers and then seeds and finally dies, form its **life history**. Anyone can follow the life history of a common plant who will take the trouble to plant the seeds, keep them watered, and study the growing plant. It is perhaps simplest to begin by growing beans and peas, as they are large seeds and easily obtained.

Beans and peas.—The fruit of the bean plant and of the pea plant is in each case a **pod,** inside which the seeds are attached by little stalks along one edge (Fig. 5).

When the pod is ripe it opens, and the seeds fall out; and on each seed is a mark, called a **scar**, showing where it was attached to the pod. It is difficult to make out the structure of the bean or pea while it is dry, but after the seed has been soaked in water for a few hours it swells and the outer skin can be taken off easily. When the scar is pressed

gently, a drop of water comes out of a small hole near one end of the scar. Moisture is necessary in order that the seed may begin to grow. Most of the water soaks through the seed coat.

The seed-leaves.—The soaked bean, after the outer skin has been removed, is seen to consist of two broad fleshy parts attached to a short, thick, pointed tip; these are the **seed-leaves.** When these fleshy leaves are separated carefully, without being broken away from the hinge, two small white leaves are found lying between them, and it is easy to see that the white leaves are continuous with the pointed white tip which unites them.

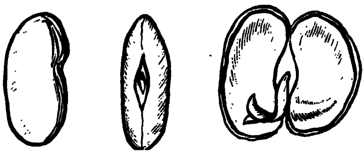


FIG. 17.—Bean seed.

These little white leaves are part of the future bean plant. The white tip itself will develop into the root. It is not difficult to make out in the pea seeds similar parts corresponding to those in the bean.

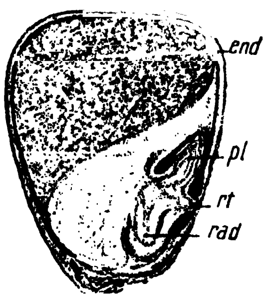


FIG. 18.—Maize grain, cut through the middle of the embryo.
end., food substance; *pl.*, plumule; *rad.*, radicle; *rt.*, origin of root.

Germination of maize.—In a grain of Indian corn (maize) there is a tough coat on the outside; this coat ends in some thin scales at the narrower part of the grain. On one side of the grain is an oval patch; and in a soaked grain of Indian corn this patch can be taken out. The patch is the little future maize plant, and consists of one broad seed-leaf, a small tip of future leaves, and another tip which will be the root of the new maize plant if the conditions

are favourable for growth. These three parts of the grain of maize make up the **young plant** or **embryo.**

The embryo rests upon a mass of white and yellow substance which, when crushed, forms a kind of flour, resembling closely that which is formed by grinding grains of wheat. The flour is composed largely of starch, and it is intended as food for the young plant. The presence of this white substance containing starch and other substances, makes maize, rice, wheat, barley and oats very valuable food both for men and animals. It also provides suitable food for the baby plants, when the seeds are allowed to grow instead of being eaten by men or animals either whole or when ground up into flour.

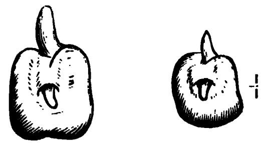


FIG. 19.—Germinating grains of maize.

This starch, however, does not dissolve in water as sugar and salt do, and cannot pass through the different parts of the plant or into the embryo. Consequently, before it can be of any service in nourishing either plants or animals, it must be changed into a kind of sugar which dissolves in water. The solution formed by the water and sugar passes easily into all parts of the growing plant.

The seed-leaves of peas and beans contain starch; and this starch changes into sugar when the embryo begins to grow or germinate. This change causes the seed-leaves to taste sweet. Very young, unripe pea seeds also taste sweet, because a sugary liquid has been brought from the rest of the plant to them, to make it possible for them to grow and increase in size. Some of the sugar is also formed in the pea seeds themselves and some of it will go to form the starch of the ripe seed.

It is well to compare the germination of some grains of wheat with that of maize grains; grains of wheat have also outer skins, one seed-leaf, and a store of starch to be

changed on germination into sugar for the feeding of the embryo. The growth and development of the little plant is called its **germination.**

These seed-leaves are called **cotyledons.** The bean and pea belong to the class of plants called **dicotyledons,** because their seeds have two seed-leaves. The maize and the wheat are **monocotyledons,** because they have one seed-leaf only.

Difference between bean seed and maize grain.—The bean is a **seed,** because it grows in a fruit, the **bean pod,** which is the ripened pistil of the bean flower. The maize is a **fruit,** because it is the ripened pistil of the flower of the maize. The scar at the broader end of the grain shows where the style was.

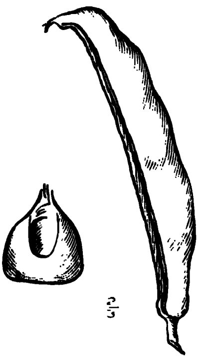


FIG. 20.—Fruit of maize and fruit of bean.

Wheat grain.—The wheat grain also is a fruit. To see how the fruit is formed, it is necessary to watch an ear of corn as it ripens, and to note how the flower changes, till all the parts have withered except the ovary—which grows very much and contains the developed seed. This growth can be studied in any corn field during the summer, whether the crop be of wheat, oats, barley or rye. The scales at the base of the flowers have to be removed before the stages can be seen properly. The growth also takes place in wild grasses, but the fruit is smaller than that of the food grains like wheat.

Ears of Indian corn can be grown in sheltered places in a garden and they form very beautiful plants.

Parts of the embryo.—The two smaller parts of the **embryo** are called sometimes **root** and **shoot**; or sometimes **radicle** (the root) and **plumule,** because the small green

leaves that come up first resemble a plume of little feathers. The cotyledons are also part of the embryo.

PRACTICAL WORK.

Examine soaked beans and peas. Note in each the scar, the hole through which a drop of water comes when the seed is pressed, the outer skin, the two seed-leaves and the future plant composed of radicle and plumule.

Draw a specimen of each, showing the parts after removal of the outer skin.

Compare an apple pip with the bean and pea; observe that the same parts are to be seen in each.

Examine a sycamore fruit, with the seed inside; note the green coiled cotyledons in the sycamore seed.

Examine an acorn with the outer shell removed, and find the same parts as in the bean.

Examine spindle-wood fruits. Make out (1) the kind of fruit; (2) the fleshy, orange-coloured outgrowth on the outside of the seed (which makes it attractive to birds, and aids therefore in the dispersal of the seed); (3) the hard pink seed, which consists of a seed coat and a small embryo with two bright green cotyledons embedded in a mass of nutritive material, which softens as the seed germinates and helps to feed the young plant.

Plant the following seeds for continuous observation in the manner indicated.

1. Beans in cocoanut fibre or sand. Some (*a*) must be kept moist and in the light. Others (*b*) must be kept moist and in the dark. Others (*c*) must be kept perfectly dry.

2. Peas in sand.

3. Maize in sand.

4. Maize and wheat over water as follows: Stretch a piece of muslin across a glass jar containing water, so that it just touches the water in one place; put the grains on the muslin.

5. Mustard and cress on flannel.

6. Acorns in acorn glasses or medicine bottles.

7. Beech and sycamore seeds in earth. These seeds probably will not germinate till spring. In spring, the young beech seedlings can be easily got from a wood (May and early June). Sycamore seedlings are usually very plentiful in districts where sycamore trees grow, and may be found in fields or on lawns.

Plant seeds for observation of the early stages of germination as follows: Place a cylinder of blotting paper inside a glass gas-jar. Fill the interior with sand, and in the space between the paper and the glass insert seeds at different levels. Keep the sand moist, but not very wet.

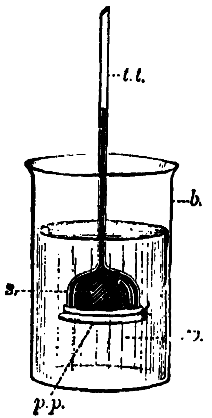


FIG. 21.—Apparatus arranged to show that starch will not pass through parchment paper.

t. t., thistle tube; *b.*, beaker; *s.*, starch; *p. p.*, parchment paper; *w.*, water.

Put a little starch into warm water and leave for some time. Notice that starch does not dissolve completely, but forms a sticky mixture with the water.

Dissolve a lump of sugar in water and detect the sugar by tasting the solution.

Add a little iodine solution (a clear yellow liquid) to the starch and water. A blue colour results. This is an unfailing test for starch. Try it on a starched white collar.

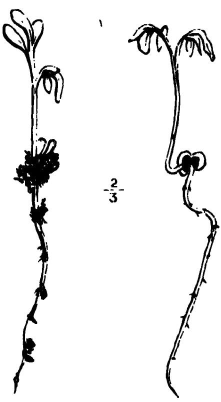
Show that starch will not pass through a membrane by covering the top of a glass thistle funnel with parchment paper. Turn it upside down in a glass of water and put starch and water into it. If the water in the glass is then tested by putting iodine solution into it, no blue colour is produced; this shows that no starch has filtered through the parchment paper.

CHAPTER V.

THE ROOT.

In a short time after seeds have been planted they change in appearance. They swell, so that the seed coat is burst off and the radicle pushes its way out of the seed. The radicle grows to some length before the plumule appears, and it begins to develop small branches as well as downy root hairs.

Root hairs.—The **root hairs** are seen best in beans germinated in a glass jar, and in seedlings grown over water. In sand, the root hairs become firmly attached to the grains of sand, but in the cases of wheat or maize growing over water, or mustard seedlings growing on flannel, the root hairs can be seen to form a delicate covering near the tip of the root, and to resemble in texture the pile of white velvet.



(1) FIG. 22. (2)

(1) Cress grown on soil.
(2) Cress grown on flannel.

The work of root hairs is to take water into the plant. When the plant grows in the ground the root hairs cling very closely to the particles of earth in order to absorb the thin layer of moisture which surrounds the tiny pieces of soil.

The roots of hyacinths grown in glasses do not develop root hairs.

The root tip and root cap.—The end of the root is rather different in colour from the rest of the root, and has no root hairs on it. A darker part can be made out and is the **root cap**; it covers the sensitive growing **tip** of the root, which is very delicate and might easily be crushed. In *water plants* the root cap is usually long and is sometimes filled with bitter substances to prevent animals in the water from eating or damaging the root tip.

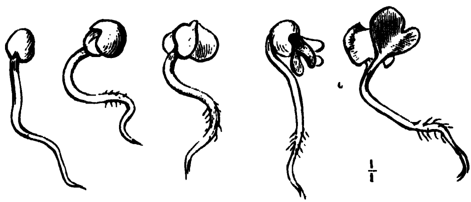


FIG. 23.—Stages in the germination of mustard seeds.

The growing end of the root pushes forward into the earth, and its slimy, solid, pointed cap helps it in its movement and protects it against injury.

The root hairs are just behind the growing point, and as the root elongates, they die and new ones grow in their place, always close to the tip.

Experiment to show the growth of the root.—In order that the growth of its root may be observed, a bean seedling is fixed on a long blanket pin and placed with the pin resting across the neck of a wide-mouthed glass jar containing water. Before the root is put in position, that is pointing downwards, fine lines are marked on it at short equal distances apart. Five lines at intervals of $\frac{1}{10}$ inch, beginning at the tip, is a convenient number.

The best way to draw these lines is by means of a piece of cotton dipped in Indian ink. This method

makes a clear fine line and does not injure the surface of the root.

When the root is observed again after twelve or fifteen hours the lines are no longer at equal distances apart. Those at the top remain in the same relative position; but the lines near the tip are much further apart. This proves that the lower part of the root grows most rapidly.

Roots always grow downward.—Probably everyone has noticed that roots always grow downward, and shoots grow upward. It can be proved experimentally in the following way that this is part of the nature of all roots.

A bean or maize seedling is fixed on a blanket pin and placed across a wide-mouthed jar containing water, so that the root and shoot lie **parallel** to the surface of the water. The plant is then left for a few hours and afterwards examined. The root is seen to have turned downwards and the shoot to have turned upwards. This experiment can be made in darkness.

Development of roots.—For more careful observation of the habits of roots the following way of studying them should be arranged:

A box with three strong cardboard, or wooden, sides, and one of glass, and a wooden bottom, is filled with fine mould. In it three or four beans which have been soaked for 48 hours are planted with their radicles close to the glass. The bottom of the box should have a few holes in it to admit of drainage. The box should be tilted slightly forward; this can be done by means of a cork cut in halves and a piece placed under each corner farthest from the glass front.

Roots grow away from the light.—In a few days, if the seedlings are left with the glass front uncovered, the roots will have burrowed into the earth and be hidden.

The precaution must therefore be taken of covering the outside of the glass with a piece of black paper (which can

which fixes the plant into the muddy layer at the bottom of the water. Water roots have usually no root hairs. Subterranean roots sometimes turn into water roots; *this* has happened with willows and elms on the banks of streams and ponds. Woody plants do not grow properly in sea or fresh water. Large water plants have usually a root which anchors them to sand, mud, or rock, and they contain air which causes their green parts to float.

Photo. Underwood & Underwood

FIG. 25.—A banyan tree.

4. Adventitious roots.—Roots may be developed from the cut ends of stems; this is seen in the taking of "cuttings" from garden plants, such as geraniums, myrtles, verbenas, fuchsias, and so on.

Roots will also grow from the leaves of some plants. If a begonia leaf be fastened to the earth in two or three places by means of hair pins, it will develop roots and eventually grow into a complete plant.

Roots produced in either of the two ways last described are called **adventitious roots.** *The climbing, or* **air roots,** of the ivy and the supporting roots of the maize also belong to this class.

In some tropical plants, **air roots** spring from the stem or branches and then hang down. They grow sometimes till they reach the ground and there fix themselves. In this way if they become thick and stiff they help to support the parent plant and also absorb water from the soil. An example of this form of roots is found in the banyan tree, which grows in the East Indies (Fig. 25). It forms "an immense living columned hall consisting of a flat expanded canopy of leaves and numerous stem-like prop-roots growing down from the boughs" (Schimper).

Work of roots.—The work of roots may be summarised in the following way:

1. They fix the plant firmly in the soil.
2. They absorb water from the soil.
3. Sometimes they serve as a store of reserve food.
4. Sometimes they act as means of climbing and as props.

PRACTICAL WORK.

Fix a seedling bean on a long pin by pushing it through the cotyledons. Fix the pin across the mouth of a glass jar containing water, so that the root lies parallel to the surface of the water; examine it the following morning and note the direction of the radicle.

Pin a seedling maize to a cork at right angles to the length of the cork, and place the cork in a saucer containing a little water. Note in a few hours the direction of the root.

Fill a small sieve with a thin layer of earth and plant mustard seeds. Hang the sieve up. Note that the roots pass out at first through the wire at the bottom, but afterwards turn up again towards the moist, dark earth in the sieve.

Arrange a box with a glass front, as described on p. 23. Observe, draw, and record the development of the roots during a week.

Observe and draw the root hairs in the plants grown *over* water, (not roots immersed in water). Repeat with mustard seedlings grown in sand.

CHAPTER VI.

THE SHOOT.

The stem and leaves.—The stem in the French bean appears first as a loop emerging from between the cotyledons. The cotyledons are drawn up by the plumule when the loop straightens, as it is formed from the part of the stem between the cotyledons and the radicle. The first true leaves begin to show after the loop has become straight.

In the pea the plumule does not draw up the cotyledons, as the loop is formed by the part of the stem *above* the cotyledons; and they remain in the same position as when planted.

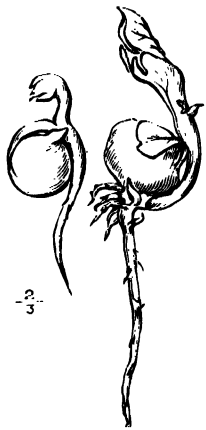


FIG. 26.—Germinating peas.

The pea germinates more rapidly than the bean, and its shoot grows very quickly. The seeds of some plants push up the seed-coat on the cotyledons, and the coat is finally split off by the cotyledons as they separate. This happens in the mustard.

In cress the seed-coat swells and becomes slimy.

Alteration in cotyledons.—As the young bean grows the cotyledons shrink and wrinkle; this happens in the pea

as well as in the bean. If the cotyledons of the germinating pea are tasted, it will be found that they are sweet. The starch in them has turned into sugar, which passes into the growing plant and nourishes it.

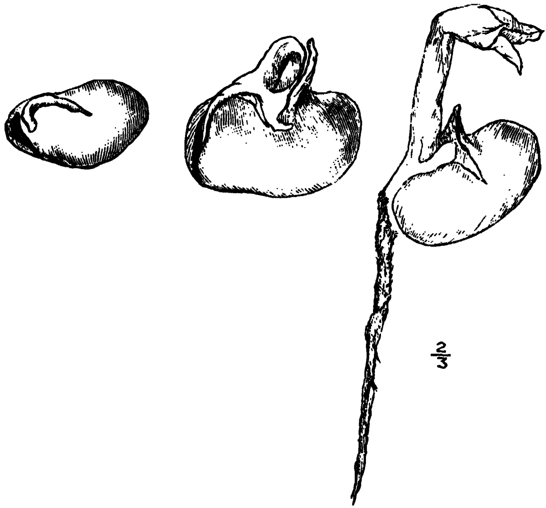


FIG. 27.—Germination of broad bean.

The fact that the cotyledons lessen in size as the embryo grows proves that their work is to supply food to the baby plant until it can form green leaves above the ground.

In some plants the cotyledons come up above the ground. This happens in mustard, beech, and sycamore seedlings, but the cotyledons are always different in shape and size from the next leaves to appear, which are the first foliage leaves. In the sycamore seedling the cotyledons which were coiled up in the seed unfold as narrow bright green strips. In the beech seedling the seed-leaves are broad and smooth, though in the seed they are folded in a kind of fan shape. It is easy to find beech and sycamore seed-

lings in May or June in or near woods where these trees grow. The wing of the sycamore fruit often carries it far from the parent tree; the beech seedlings are usually near the beech trees, as neither fruit nor seed is adapted for being carried a great distance by the wind, though they are sometimes transported by squirrels and dropped some distance away.

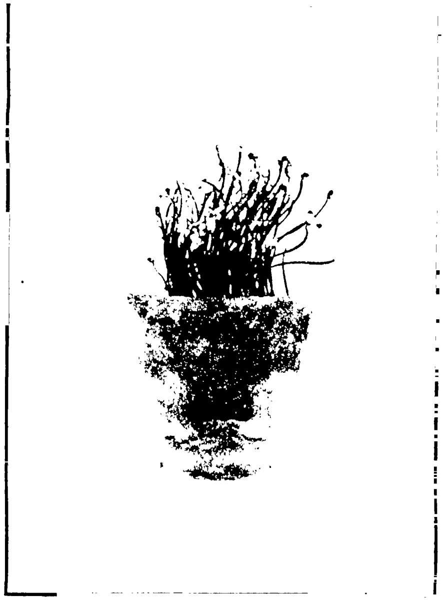


FIG. 28.—Mustard seedlings in upright pot.

The cotyledons of all plants vary much less in size and shape than do the foliage leaves. Cotyledons have usually entire margins, are most often oval, or long and narrow, in shape, and with a smooth surface which becomes green when the cotyledons spread out in the air and light. In the borage and forget-me-not the cotyledons have bristly surfaces; and in some nettles the cotyledons have stinging hairs on their surface. Sometimes they become green while still in the seed, as in the seed of the spindlewood tree. At night the cotyledons of most seedlings fold together to protect themselves and the young shoot between them from cold.

The stem.—The stem of most young plants is green and juicy. It grows upwards or towards the light. This may

be illustrated by placing a pot containing mustard or sunflower seedlings on its side, so that the seedlings are parallel *to the ground. In a few* hours they are all turned at right angles to the ground.

FIG. 29.—Mustard seedlings after being placed horizontally for some hours.

"The young stem grows blindly but unerringly upwards towards light and air, as the root downwards towards moisture and darkness" (Geddes).

If any part of a plant which usually grows upward, such as stem, leaves, and flower-stalks, is forced out of the upright position it will always return to it as long as the plant has the power of growing.

If seedlings are grown in a glass vessel over water and placed where much more light comes from one side than from any other direction, the young stems all bend towards the light and the young roots away from it (Fig. 30).

FIG. 30.—Mustard seedlings grown over water, and illuminated chiefly on one side. The roots are all bent away from the light.

When a plant is grown in a room with a window on one side, the plant will always bend towards the window, and most leaves and flowers will

grow on the side nearer the light. This may be seen also in plants grown in a garden shaded on one side by trees.

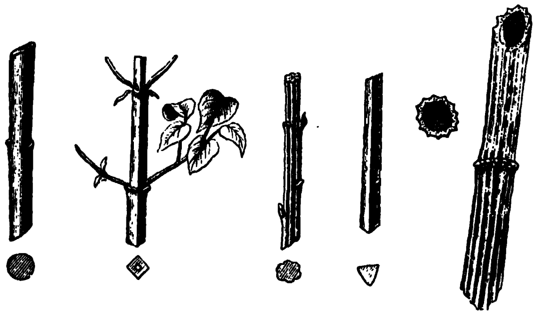
FIG. 31.—Evening primroses grown in garden shaded on two sides by trees; flowers produced on side exposed to fullest light.

Difference between stem and root.—Leaves grow from the stem. This fact can be made out even in the young plant while it is still in the seed; and in this way stems may as a rule be most easily distinguished from roots. The outgrowths from roots (excluding root hairs) are branches of the root, and are like the root from which they arise.

The tip of a growing stem is always a bud, consisting sometimes of young leaves and sometimes of a young flower. Roots ordinarily have no buds.

The place at which a leaf grows on a stem is called a **node**. The space between two nodes is called an **internode.** The nodes and internodes can be distinguished, even in plants which shed their leaves in winter.

Sometimes the stem is jointed at the nodes; this is the case in the pink and stitchwort. In some grasses the stem has a thickened ring round it at the nodes, but the thickening really belongs to the base of the leaf. The bamboo has very thick rings round its stem at the nodes.



Round stem. Square stem. Ribbed stem. Triangular stem. Coarsely ribbed stem.

FIG. 32.—Shapes of stems.

Shapes of stems.—Stems are of many different shapes: the following are examples :—

1. Round: grasses and trees.
2. Square: the dead nettle.
3. Triangular: the sedge.
4. Ribbed: the hemlock.
5. Flattened (winged): the everlasting pea.

Cactus plants have irregularly-shaped stems. As these plants are specially adapted for life in dry places, the stems have a very thick skin, and are juicy inside. Other plants which resemble the cactus plants in having leafless, irregular, much swollen, juicy stems are the euphorbias or spurges

which grow in Africa and the East Indies (Fig. 33). The places where they grow are very dry, on sandy or rocky soil, and in districts where no rain falls for about three quarters of the year. The outer skin of the stems of such plants is very thick, and in the middle of the stem is collected a store of moisture. Plants with such thick juicy stems are called **succulent** plants, and have been compared to camels, which can provide themselves with a supply of water to last for some time. These plants obtain their fresh supply of water every rainy season.

FIG. 33.—Euphorbia, a plant with swollen stems.

Plants which live for several years have usually woody stems. Trees show the most striking examples of this kind of stem, and many live for several hundred years. The older the tree is the thicker is its stem. New wood is added each year and forms distinct layers, because the wood formed in autumn has a finer texture than that formed in spring; so that when a tree is cut down its age can be calculated by counting the rings.

FIG. 34.—Section of larch stem, showing yearly rings of wood.

This applies to trees in temperate climates where the seasons are well-marked. In this way the age of several trees has been calculated either when they have been cut down by man or have died naturally. Every kind of tree has a certain average length of life just as animals have. The extreme age attained by chestnut trees is stated to be two thousand years, of the oak two thousand, of the beech three hundred, and of the ash from two hundred to three hundred years—but probably very few trees reach the age of over a thousand years.

FIG. 35.—Thickened tree trunk at Burnham Beeches.

Plants which only live for one or two years usually have soft stems.

The trunks of trees differ from the green stems of plants which only live for one or two years in being covered with **bark**. This is formed through a layer containing cork which grows below the outer covering or cortex of the tree-trunk, cutting off the supply of water to the cortex. Whatever part of the tree-trunk lies outside the cork dries up and dies. The cork-layer and the cortex together form the bark of the tree. Every kind of tree has its own characteristic bark (see Chapter XXI.).

Surface of stems.—The surface of the stem may be

1. Smooth, as in the hyacinth, lily of the valley, and snowdrop.

2. Covered with a coating of fine wax, resembling the "bloom" on a grape or purple plum, as in the tulip flower-stalk and the stem of sea-holly.

3. Hairy, as in the African and field poppy. In the catch-fly the hairs are sticky, and prevent small insects creeping up the stem to the flowers. In the stinging nettles the hairs are large and brittle, and when they break off an acid liquid comes out which irritates the skin of anyone who touches it.

FIG. 36.—Scarlet runner beans; twiners.

4. Prickly, as in briar roses.

5. Thorny and spiny as in the furze and blackthorn.

Most stems are erect, but some plants have weak stems which either trail on the ground or make their way upward by attaching themselves to surrounding objects (Fig. 36).

Stems which trail on the ground are usually called **prostrate** stems if they become woody and last for many years. Trailing stems which do not become woody and which develop small roots are called **creeping** stems. The roots penetrate into the ground and often draw part of the stem down into the soil (Fig. 40).

Ways in which weak stems climb.

1. Scramblers: Wild rose and blackberry.
2. Root climbers: Ivy.
3. Twiners: Hop, honeysuckle, convolvulus and bean (Fig. 36).
4. Tendril-bearers: Bryony (Fig. 37) and passion flower.

FIG. 37.—Bryony, showing tendrils.

The Virginian creeper has tendrils which attach themselves to walls by small sucker-like discs which harden, and cannot be loosened by wind (Fig. 38).

The use of climbing for the weak-stemmed plants is to reach the light and air as easily as possible. It costs a good deal of plant-energy and food to make a strong woody stem, and "it is a real economy to get a tree or wall to bear the weight and so relieve the plant of the necessity of making a stout stem."

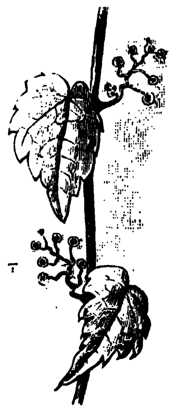


FIG. 38.—Virginian creeper.

Guilds or societies of dependent plants.—Plants which depend to a greater or less extent on other plants for their existence have been grouped into four **guilds**, or societies, of which the climbing plants form one.

The guild of climbers is found nearly everywhere. Climbers do not grow in the far north or in very high places; some, from which the examples in this book have been taken, are inhabitants of

temperate regions, but by far the greater number, probably ninety out of every hundred, grow in tropical climates and prefer damp places.

The other guilds of dependent plants will be described later.

PRACTICAL WORK.

Draw a bean seedling and a pea seedling.

Examine a growing bean seedling and a growing pea seedling each day till the first foliage leaves unfold. Describe any difference in the position of the cotyledons in the two seedlings.

What happens to the seed-coat in the germinating mustard seed? What happens to it in the germinating cress seed?

Place horizontally a flower-pot in which mustard seedlings are growing. Leave it for a day. What happens to the seedlings?

Put some growing seedlings (either in earth or grown over water) in a dark cupboard with a glass door. Note in a few hours the direction of the stem and leaves.

If the seedlings have been grown with their roots in water, in what direction do the roots turn?

Look at the stem of the wall-flower. What shape is it? How are the leaves arranged? Draw the stem and leaves of the wall-flower. Look at the root of the wall-flower. Can you find any leaves or buds on it? Are the branches of the root different from the main root? Draw the root of the wall-flower.

Cut across the stems of the hyacinth, dead nettle, sedge, hemlock, and ash twig. Draw the shape of each.

Collect as many climbing plants as possible. Draw each, so as to show the way in which it climbs. Describe any differences you observe as to the direction in which twining plants twine.

CHAPTER VII.

UNDERGROUND STEMS.

Underground stems.—Some kinds of stems do not grow above ground, but they can always be distinguished

FIG. 39.—Potato plant, showing tubers.

as stems because they bear buds, or scales, or thickened leaves.

1. **Tubers.**—The potato is an underground thickened

portion of a stem. The "eyes" are small buds, and if the potato is kept moist and warm the "eyes" grow into new plants. The chief substance in the potato is starch. This can be shown by testing with iodine solution. When a slice of potato is touched by a few drops of iodine solution it turns blue, as did the starch from the wheat, rice and Indian corn.

If a potato plant be grown from seed it grows at first just like any other seedling; but soon small branches arise from the stem and turn downward into the earth, where they become thickened and rounded and form "new potatoes."

Potato plants can also be obtained from old potatoes. Each potato is cut into pieces in such a way that each piece contains an "eye." The pieces are then planted. From each "eye" grows up a new plant, with root developing below and shoot formed from the bud coming above ground.

Thickened underground stems like the potato are called **tubers.**

2. Creeping underground stems.—There are two kinds of creeping stems. One is very thick, and usually contains a large amount of food-substances; the other is slender.

Examples of the thick underground stems are seen in the iris and Solomon's seal. Perhaps the most common example is the bracken fern. Anyone who has tried to pull up a well-grown bracken fern from a hedgebank knows how difficult it is to do so, on account of its strong, thick, creeping, underground stem.

The long, thin creeping stem is found very often in plants which grow in sandy places, and it helps their fibrous roots (p. 25) in binding the soil together. Sand sedge and couch grass are common examples of the slender creeping stem.

Both kinds of creeping stems have small roots growing at

intervals from the lower side, and leaves and buds from the upper side. A new plant can be grown from any piece of one of these stems if it has a leaf bud on it. Farmers find great difficulty in getting rid of couch grass in fields because of its numerous roots and long creeping stems, which extend very quickly. The creeping stems of couch grass are very persistent and have sometimes bored through roots of trees and potato tubers; they will even force a way through tinfoil. Where it is desirable to have sandy soil bound tightly together the couch grass has proved very useful.

FIG. 40.—Couch grass, showing creeping stem.

3. Bulbs.—Many spring flowers grow from **bulbs**. On the outside of a *hyacinth* bulb are thin papery **scale leaves**; below these are thick fleshy leaves overlapping each other; and in the middle of the bulb is the flower bud. The leaves and flower bud arise from a short, round, flattened stem at the bottom of the bulb. The arrangement can be seen more clearly when the bulb is cut across the middle. The daffodil, onion, and tulip are bulbs composed of scale leaves and fleshy leaves growing from a flattened stem. Fibrous roots from the lower surface of the stem grow when the bulbs are planted. The growth of a bulb can be seen very clearly in a hyacinth or onion grown over water in a hyacinth glass.

4. Corms.—The crocus grows from something resembling a bulb, but if this be cut across it is found to consist of thin scale leaves surrounding a very much thickened oval stem, which is white inside. This kind of bulb is called a **corm.** That it contains starch can be shown by testing with

iodine solution. In Syria the crocus corms are roasted, ground into flour, and used as food because of the starch contained in them.

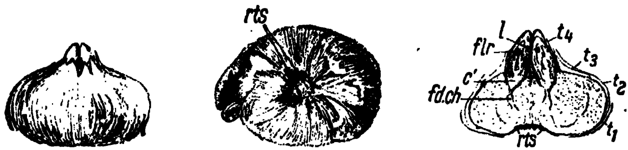


FIG. 41.—Crocus corms, seen from the side, from below, and cut across. *c'*, base of bud which will grow into next year's corm; *fd.ch.*, food channel; *flr.*, flower bud; *l.*, young leaves; *rts.*, roots; t_1, t_2, t_3, t_4, scales covering corm.

PRACTICAL WORK.

Examine and draw the tuber of the potato, noting the "eyes." Plant a potato in sand and keep it warm and moist till it begins to sprout. Where do the shoots appear?

Examine and draw the underground stems of the bracken fern, iris, and couch grass. Notice the leaves arising at nodes, and the fibrous roots on the lower side.

Examine the hyacinth or tulip bulb. Cut one across and draw the arrangement of leaves. Plant a hyacinth bulb over water in a glass for continuous observation. Write down the time of appearance of roots and leaves. Keep it in the dark till the roots have formed. What is the reason for this?

Examine and describe corms of the crocus.

Test a slice from the tuber of a potato for starch.

Test a slice across a thick underground stem of bracken fern or Solomon's seal for starch.

Test a crocus corm, cut across to expose the white surface, for starch.

CHAPTER VIII.

FALL OF THE LEAF. FORMATION OF WINTER BUDS.

Fall of the leaf.—The shoot always ends in a bud. Buds also arise in the angle between a leaf and stem. Buds can be studied most easily on those trees which lose their leaves in autumn. Buds are really young branches containing the future stem and leaves; and they are formed while the tree is full of leaves during the summer-time. As autumn approaches, the tree prepares for winter. The green colour in the leaves changes to bright yellow, red, and brown. Early in summer across the stalk of each leaf close to the branch a layer composed largely of cork begins to form. In time this layer cuts off the supply of water to the leaf and causes it to be attached to the stem so slightly that it is snapped off easily by a gust of wind. The withered leaves of beeches lie close to the stem. In young trees these leaves often remain on their parent trees most of the winter. The same thing happens also with young oaks. When the leaf falls, a waterproof scar can be seen where the leaf was fastened to the stem. Usually a bud is found immediately above the scar, prepared by the tree in readiness for next spring. Many more buds are formed than actually open. Buds which do not open are called **sleeping buds**. On the lower part of the trunks of young trees many such buds may be found. If the top of the tree is cut off, some of

the sleeping buds lower down grow and make the tree bushy in appearance. Pollard willows are an instance of this; so also are fruit trees which have been pruned and trained so that the branches spread horizontally.

Buds of trees.—Tree buds are well protected against winter weather.

The **horse chestnut** bud is dark brown and very sticky. It is almost impossible to take it to pieces neatly until the bud has been put into methylated spirit, which dissolves the sticky covering. Beneath these brown, resinous, outer scales are thin papery ones. Below the papery scales are leaves covered with woolly hairs. These woolly hairs keep the baby leaves from sudden cooling, and the outer scales protect them against rain and against being eaten by insects or birds. The leaves are very downy and folded closely together. In some of the chestnut buds the flower bud is present; it is pinkish white and covered with soft woolly hairs. The woolly coverings do not keep the bud actually warm, but they preserve it from rapid chilling.

Photo. Flatters & Garnett, Ltd.

FIG. 42.—Opening of buds of horse chestnut.

The buds of the **beech** are long and pointed, with smooth overlapping brown outer scales.

The bud of the **ash** is protected by black scales, mentioned by Tennyson, "more black than ash-buds in the front of March." Inside are the young leaves, with a covering of down.

In the **wayfaring tree** (a wild guelder rose) the buds are covered with tiny star-shaped hairs which probably protect the buds from rain.

Plants which live in temperate or cold countries have their buds protected in the ways mentioned, by scales, resin,

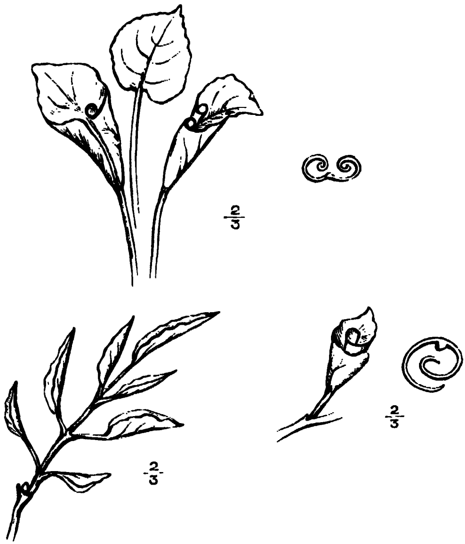


FIG. 43.—Folding of leaves in bud; violet, ash, apricot.

and hairs. Plants which die down during the winter in temperate countries, or which live in tropical countries, and so are not exposed to cold severe weather, have as a rule naked buds. The geranium and pelargonium are examples of this.

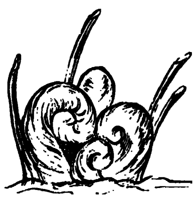


FIG. 44.—Fern leaves in bud.

Arrangement of leaves in buds.—Leaves are arranged in many different ways in buds. They are sometimes folded like a sheet of notepaper; sometimes they are pleated like a fan; sometimes they are rolled either from side to side, as in the apricot (Fig. 43); or from

top to bottom, like the fern, which is curled like an old-fashioned crook (Fig. 44).

Some leaves are crumpled, not folded regularly.

PRACTICAL WORK.

Examine a geranium and a branch of beech with withered leaves on it. What are the differences between the geranium leaves and the beech leaves? Break a leaf from the stem of the geranium; what kind of mark is left? Break a leaf from the branch of beech; what kind of mark is left? Draw it.

Draw the mark left where a leaf has fallen from a horse chestnut branch.

Soak a green leaf of the geranium plant in methylated spirit; what change takes place in its appearance? Test for starch the leaf which has been soaked by putting iodine solution on it. What happens? What is the cause of the change?

Soak a withered leaf of beech in spirit and then test it for starch. What happens? What do you infer from the result of this experiment?

Examine and draw the buds of chestnut, sycamore, ash, and beech. Describe how the buds are protected in each case.

Draw the same buds so as to show how the leaves are folded in each. (Dissolve the resin on the chestnut buds by soaking them in methylated spirit before taking them to pieces.)

Keep branches of chestnut, sycamore, ash, and beech with their cut ends in water for several weeks. Draw them at different stages of unfolding of the buds.

Examine and draw the leaf-buds of violets, primroses and daisies. How do they differ from tree leaf-buds?

(About February or March is a good time for observing the opening of buds of trees on branches kept in water.)

CHAPTER IX.

LEAVES.

Kinds of leaves.—1. Seed-leaves.—The seed-leaves or cotyledons have been studied already. These leaves sometimes come above the ground (as in mustard, cress, beech, and sycamore), but they are always simpler in form than true foliage leaves.

2. Protecting leaves.—Bud scales and **bracts** are included under this heading. Bracts are leaf-like structures which grow on the same part of the stem as the flowers do. They are often thin and dry, like tissue paper in texture, and sometimes are large enough to wrap completely round the flower when it is in bud. These protecting bracts occur in the crocus, narcissus, and daffodil.

3. Foliage leaves.—Foliage leaves are ordinary green leaves. They differ greatly in shape, size, surface, and way of growing; but they consist usually of two well-marked parts, and have veins on their surfaces.

The two parts of a foliage leaf are the **leaf-stalk**, which fastens the leaf to the stem, and the broad flat **blade**, in which veins can usually be seen. The part of the leaf-stalk by which it is attached to the stem is sometimes wide and may partly surround the stem. Sometimes the stalk grows out into little wing-like structures; these are to be seen on rose leaves.

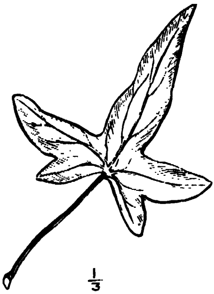
Some leaves have no leaf-stalk; examples are found in the daffodil, iris, crocus, and tulip.

Shapes of leaves.—There are many different shapes of leaves. The shapes may be classified as follows:

1. Leaves which are long and narrow are called linear; examples are seen in grasses and the crocus.

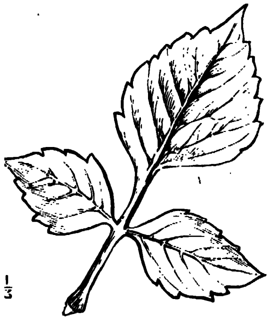
2. Leaves which are sharp-pointed and shaped like a needle are called needle-leaves. Examples are found in the pine and fir.

3. Broad, flat, long leaves are called lance-shaped. The wall-flower affords a good instance.



$\frac{1}{3}$

FIG. 45.—Simple leaf, with entire margin.



$\frac{1}{3}$

FIG. 46.—Compound leaf, toothed margin.

4. Spoon or spade-shaped leaves. The daisy is an example.

5. Kidney-shaped leaves, as, for instance, ground ivy.

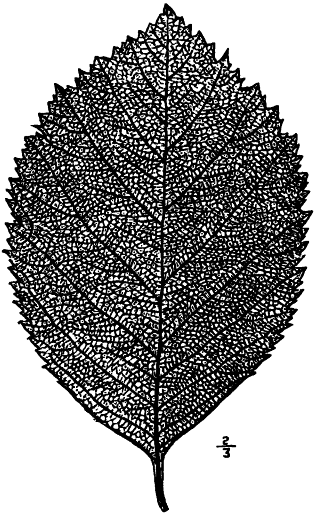
6. Ovate; as in the elm leaf.

7. Heart-shaped leaves; as in the case of the violet.

Leaves may be classified as simple or compound. **Simple** leaves are those which have one leaf-blade which may be partly divided. **Compound** leaves are those in which the blade is divided up completely into separate leaflets. An ivy leaf is simple; a rose leaf is compound (Figs. 45 and 46).

The edges or **margins** of leaves are sometimes entire and sometimes indented or toothed. The teeth vary in

kind; they may be rounded, as in the ground ivy; or sharp, like the teeth of a saw, as in the rose.



$\frac{2}{3}$

FIG. 47.—Net-veined leaf.

Leaves are arranged on a stem, either opposite each other, or at different levels on opposite sides of it, or spirally. If a piece of cotton be twisted round a stem from which the leaves have been taken, so that the cotton passes over the places where the leaves were, the shape it takes round the stem is a spiral. A corkscrew is an example of a spiral.

Veining.—Leaves are **net-veined** or **parallel-veined.**

Monocotyledons (p. 18) have usually parallel-veined leaves. The maize, lily of the valley, crocus, snowdrop and tulip are instances. The principal veins are parallel; they run down the length of the leaf and are connected by branch veins (Fig. 48).

In net-veined leaves, smaller veins form a network; they are branches of the principal veins (Fig. 47).

The veins are seen most clearly in skeleton leaves. In winter, in woods, if the dead leaves are turned over carefully some can be found from which the softer parts have rotted away, leaving the framework of the leaf as a delicate tracery. Skeleton leaves can be prepared artificially by soaking green leaves

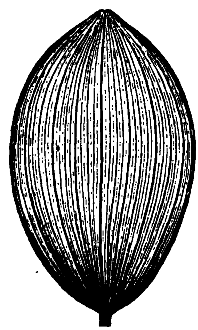


FIG. 48.—Parallel-veined leaf.

in water for several weeks and then scraping off the softened green part.

Surfaces of leaves.—The surface of a leaf may be hairy as in the stinging nettle and elm; smooth, with a coating of wax, as in cabbages and tulips; woolly as in lamb's ear; and smooth, with a thick skin, as in the house-leek and stonecrop.

Adaptation of leaves to resist wind, snow, and rain.—The leaves of trees are adapted to yield to the force of the wind, and so to avoid being torn off before their time. They have usually flexible leaf stalks. These stalks are very mobile in the "light, quivering aspen," and are likewise very flexible in the pear, apple, and birch—the "lady of the woods"—with its delicate, quivering leaves.

Onion leaves, which are tubular, resist the bending action of the wind; so, too, do the stems of the food grains.

Evergreen trees and shrubs, which grow in cold and temperate countries and are exposed to wind, have simple leaves. These trees have usually narrow and pointed leaves which catch the wind very little. Examples of simple glossy-leaved evergreens are the laurel and rhododendron. Examples of evergreen forest trees are pines and firs.

These evergreen trees are also adapted to withstand snow, which slips easily from their sloping boughs. The snow would break to pieces the branches of a forest tree in full leaf, such as chestnut. Possibly the glossy surfaces of the leaves of holly, laurel, and other evergreen shrubs prevent heavy snow resting on them for a time long enough to break the plants.

In temperate countries most trees lose their leaves in winter. Probably this is because the trees would be more damaged by wind and snow if they were in leaf than when they had bare boughs. In the tropics there is no definite season when the fall of the leaf takes place.

The leaves of plants living in places where a heavy rainfall occurs have often long dripping points, by means of which the surplus water is drained off. Such points can be seen on the leaves of some begonias. Dripping points are found on leaves which are easily wetted. Some plants which grow in damp tropical districts have glossy leaves from which the rain slips quickly. The India-rubber plant has leaves of this kind.

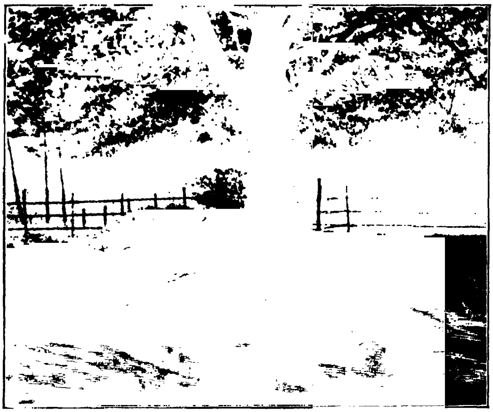


FIG. 49.—Tree, with roots exposed.

In almost all trees the leaves slope outward and are so arranged that the rain flows along the slanting surface of the upper leaf to the tip. The rain then collects in drops and falls upon the lower leaves, and so passes finally to the leaves on the lowest branches, afterwards falling to the ground and forming a band of wet earth round the dry space close to the tree trunk. The water soaks into the ground, and eventually reaches the absorbing roots of the tree below the ring of wet earth, because these have spread out below ground as the branches have spread above.

The veins of leaves which conduct water in this way

are channelled and so help the rain to reach the tip of the leaf, or of the leaf-lobes. These channels can be seen in the leaves of ivy and spiraea.

The leaf of the nasturtium is circular; it is, however, not attached to the stalk directly in the middle but slightly to one side; it is thus tilted and water runs off it easily.

Plants which grow from deep tap-roots sometimes have their leaves arranged in a rosette on the ground, and always

FIG. 50.—Rosettes of London pride.

have them so placed that the surfaces slant towards the centre of the plant. The water collected flows towards the root. The rosette arrangement is seen in the daisy, primrose, London pride (Fig. 50), dandelion and house-leek.

Leaves sloping inward are found in the hyacinth, tulip, and other plants growing from bulbs. The young leaf of the lily of the valley is coiled up like a sugar-bag or trumpet. The leaves of plants which grow naturally in the moist shade of woods, or near brooks where spray may fall on them, have often a velvety surface, so that the water spreads out into a thin layer which dries up quickly. Examples

of this arrangement are seen in some "foliage" plants grown in greenhouses, such as coleus; they are chiefly natives of the tropics.

Marsh and water plants often have two kinds of leaves; finely divided, submerged leaves and floating leaves more or less disc-like, with the lower surface touching the water.

The water crowfoot has thread-like, submerged leaves in the water and ordinary foliage leaves rising into the air above the surface of the water.

PRACTICAL WORK.

Collect several kinds of leaves. Draw them. Notice whether they are cotyledons, protecting leaves, or foliage leaves.

Write under each drawing what the shape of the leaf is, what kind of margin and surface it has, and the place where it grew.

Prepare skeleton leaves by soaking foliage leaves in water containing a little chloride of lime. When the green part of the leaf is soft, scrape it away carefully. Wash the skeleton leaf in pure water. Put a little gum on one side of the leaf and place it on black paper.

Notice on a windy day the leaves of aspen, birch, apple, onion, and wheat. How does each leaf meet the force of the wind?

Where does the rain falling on a large tree finally reach the ground?

How far do the roots spread under the ground in any tree you have seen which has roots exposed?

Water a daisy plant. How does the water flow over the leaves?

Examine and draw the leaves of the water crowfoot in water. What differences are there between the leaves above and the leaves below the water?

CHAPTER X.

THE WORK OF ROOT, STEM AND LEAVES.

Work of root.—The need of plants for a constant supply of water is known to everyone. Most people know also that in the case of growing plants the water is supplied through the earth and taken up by the roots. The part of the root which absorbs water is near the tip and covered by root-hairs. These root-hairs were observed in the germinating seedlings, and can be traced in the full-grown root by noticing to what part of the root the grains of soil cling most closely.

When a plant is placed with its roots in water to which a few drops of red ink or cochineal have been added, and, in a short time, the roots are cut across, it will be found that the coloured liquid has passed into the root and formed some red spots in it. When the plant is left for a longer period with its roots in the red water, the colour will penetrate into the stem, leaves and flowers, travelling along definite lines, or canals, which may be called **water paths.** These paths are straight in the stem, bend outward to the branches and the leaves, and form the veins. There are a great many water paths in the plant and they are all supplied from the root.

Root pressure.—When a cabbage is cut from the stem, water comes freely from the part left connected with the root; this is because the root is pumping up water which

ordinarily would supply the water paths of the whole plant. This action of the root is called **root pressure.** The same thing is seen if a sunflower stem is cut off near the earth. Water flows freely from the end left above ground.

Importance of water taken in by roots.—The water taken up by roots from the ground contains substances from the earth dissolved in it. These substances are called mineral **salts**, and are necessary for the continued life of all plants. This fact can be shown by growing two seedling beans, one in distilled (or chemically pure) water and the other in ordinary soil. After a time the bean grown in distilled water droops and dies, while the seedling growing in soil forms a vigorous plant. There is a similar difference when the second seedling is grown in water containing the same mineral matters as those which are found in the earth. Such a solution is made of common salt, nitre, Epsom salts, plaster of Paris, and phosphate of lime, dissolved in distilled water to which a very small amount of chloride of iron has been added.

By leaving some of these substances out of the solution, the materials needed for certain parts of the plant have been discovered. If there be no iron in the solution, the leaves and stem of the plant growing in it are pale yellow, but they turn green when a drop of liquid containing iron is added to the solution. If there be no nitre present, the plant is dwarfed and stunted. Different kinds of plants absorb different proportions of minerals from the soil. This fact has long been known to farmers, who have learnt by experience to grow different crops in successive years on the same field, such as turnips, barley, and clover, because these do not use the mineral salts in the same proportions.

Plants can only take in **dissolved** substances by their roots. When a plant is placed with its roots in a mixture of powdered carmine and water, no red streaks are to be found either in root or stem. This result shows that

none of the carmine has entered the water paths, because powdered carmine does not dissolve in water.

In the stem of a plant the water paths can be distinguished as threads near the outside of the stem. If the paths are traced carefully to the leaves it will be seen that one passes into each leaf and breaks up to form the veins.

Transpiration.—Place a geranium plant in a pot under a bell jar. After the surface of the earth in the pot has been covered completely with tin-foil and left for a few hours, the surface of the bell jar will be covered inside with drops of moisture. This water must have been given out by the plant, as the tin-foil prevents any evaporation from the earth in the flower pot. The passage of water from its green leaves into the air is called **transpiration.**

When a plant is exposed to the air and not supplied with water, it withers owing to the loss of water by transpiration through its leaves. The same thing happens if cut plants are not placed in water quickly after being gathered.

Loss of moisture from leaves.—To show that a green leaf loses moisture, it can be tested with blotting paper which has been dipped into a solution of **cobalt chloride** and allowed to dry. Paper which has been soaked in this way is blue when dry and turns red when exposed to damp. If a piece of it be held near a green leaf on a growing plant, it gradually turns pink; thus showing that moisture is coming to it from the leaf. To find out which side of the leaf gives off moisture more quickly, two pieces of cobalt chloride paper are cut to the size of the leaf; one of them is laid on each side of it and the whole put between two pieces of glass. The piece on the lower side of the leaf turns pink more rapidly. This result shows that the lower surfaces of leaves transpire more quickly than do the upper.

That water is lost chiefly from the lower surfaces of leaves can be shown also by covering them when on a cut branch with a thin film of oil. These leaves keep fresh for a longer

time than do leaves not so covered, because the oil checks the loss of water vapour from the under side. The water vapour passes from the leaf through little openings or **mouths**, which are more numerous on the lower side of the leaf. The oil in the experiment fills the mouths described, and so prevents the water vapour from passing out. There are many thousands of such mouths on every leaf, and they can only be seen by the help of a microscope.

PRACTICAL WORK.

Put the end of the root of a white radish in red ink and water. What change takes place in the appearance of the root?

Put the root of a celery plant in red ink and water. What happens in the stem of the celery plant?

Place the cut end of a narcissus or snowdrop with flower and leaf in the mixture of red ink and water. What changes take place in the appearance of leaf and flower?

Cut across a cabbage, dahlia, or sunflower stem immediately above the ground. What happens to the end left in the ground attached to the root? What is the cause of what you notice?

Grow some seedlings in distilled water. Grow other seedlings in water containing the following salts (Sachs' solution). This solution is best made up by a dispensing chemist. It contains the minerals found in ordinary earth; such solutions are called food solutions.

Potassium nitrate (nitre) - - - - -	1 gram.
Sodium chloride (common salt) - - -	0.5 gram.
Calcium sulphate (plaster of Paris) - - -	0.5 gram.
Magnesium sulphate (Epsom salts) - - -	0.5 gram.
Calcium phosphate - - - - - -	0.5 gram.
Distilled water - - - -	1000 cubic centimetres.

A drop or two of iron chloride to be added to the solution.

In arranging seedlings to be grown in food solutions it is best to have at least two for each experiment.

The seedlings (peas give very satisfactory results) should be fixed between two halves of a pickle cork. They should

be wrapped in glass wool or asbestos at the point where they are to be fixed between the pieces of cork. This plan prevents both injury by pressure and the growth of moulds.

Grow (1) two seedlings in Sachs' solution.

(2) Two in the same solution but without iron chloride.

(3) Two without calcium compounds.

(4) Two without magnesium compounds.

Place the solutions in glass cylinders which can be covered with paper to prevent too much light reaching the roots. The solutions should be renewed each week, and the experiments continued until the peas in the Sachs' solution bear flowers and fruits.

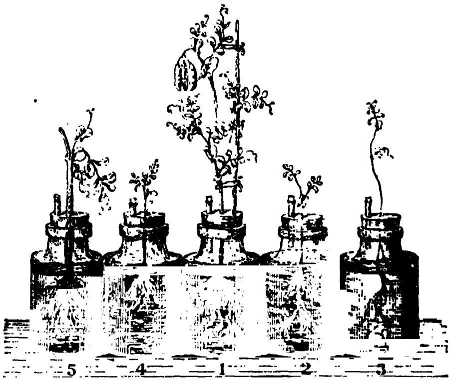


FIG. 51.—No. 1. Pea plant in full Sachs' solution. No. 2. Pea plant without potash. No. 3. Pea plant grown without salts containing nitrogen. No. 4. Pea plant grown with soda instead of potash. No. 5. Pea plant grown without calcium.

Draw the seedlings at intervals of four or five days.

Try the experiments on transpiration as described in the text.

CHAPTER XI.

WORK OF ROOT, STEM AND LEAVES (*Continued*).

Protection of leaves against too much water on them.—The position of the mouths on green leaves can be found by dipping the leaf into water. Parts of it are wetted and parts remain dry. The mouths are in the dry patches, as they are always protected specially against the danger of being choked with water. In willows and rushes, which live near streams and pools, the leaves have a thin coating of wax. The two white stripes on the under side of fir leaves are formed of wax. The iris has a film of wax on its leaves. In cabbages there are mouths on the upper side of the leaves and also a coat of wax. It is easy to see how the water rolls off a cabbage leaf.

Some plants have a coating of fine hairs on the lower surface of their leaves, and this coating prevents the mouths from being wetted. This arrangement exists in the raspberry, coltsfoot, and several other plants.

Protection is supplied to plants, the leaves of which are occasionally under water, by the mouths being sunk in little hollows. The mouths are guarded from the water reaching them by small elevations all over the lower skin of the leaf. This arrangement is found in marsh plants.

The rate of taking in and giving out of water is important in causing different characteristics of plants. Some plants are adapted for giving out water very rapidly and others

are specially arranged for retaining water. The first kind are plants which live in places where there is no danger of being dried and where the chief danger is the stagnation of the water supply in which their mineral food is brought.

Plants living in dry places.—Plants which have a difficulty in obtaining a regular supply of water are provided with devices for assisting them to absorb water and for limiting the amount transpired. The leaves of such plants are often relatively small, and are sometimes covered with silky hairs closely interwoven, containing air entangled among them, which prevent the surface of the leaves from losing too much water. In some cases the leaves are represented by thorns or spines (Fig. 33). The outer skin of the leaf and stem is much thickened and the mouths are sunk in little depressions. Sometimes the plants have a supply of water-storing tissue. These plants grow on dry or salt soils, or in very dry air, and they are consequently guarded from the dangers of absorbing too little or losing too much water. Some such plants are found in deserts, for example, cactuses; some grow on rocks and walls, as stonecrop and saxifrage, the name of which means **rock-breaker**; others are found on the sea-shore, as sea-holly.

FIG. 52.—Willows growing towards water.

Plants adapted for this kind of life have small thick leaves, often leathery, fleshy, or partly suppressed, as in the cactus, where the stem has become juicy and contains a gummy sap and the leaves are nothing but thorns which protect the plant from being eaten. Sometimes the leaves are open on dull days or in the early morning, but close up when the sun is bright. In the eucalyptus the leaves are arranged so as to catch the sunshine edgeways. Plants which live in dry places have well-developed roots. Garden plants can be secured against drought by deep planting; roots of trees often find their way to water (Fig. 52). Cases have been known of water-pipes being choked in this way.

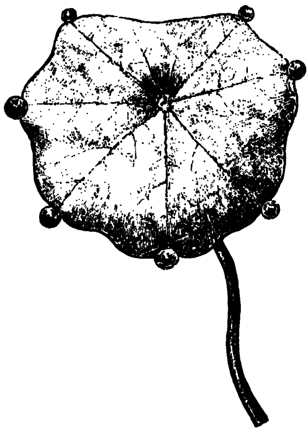


FIG. 53.—Nasturtium leaf giving out drops of water.

Plants living in damp places.—Plants which live in damp places have to be protected against excess of water; they have usually weak roots which do not exert great force in pumping water into their stems and leaves. Their leaves are large and they have well-developed, numerous mouths. In water lilies, the mouths are on the upper surface of the leaves since the lower side is in water. Plants with upright leaves have mouths on both sides of the leaf.

Some plants have special means of getting rid of an excess of water, which have been compared to the "sweat-glands" by which perspiration escapes from the skin of animals. These plants are found chiefly in the tropics, but some English plants also have them. Examples of such English plants are the cabbage and the lady's mantle, or

"dew-cup." The large drops seen on cabbage leaves are not composed entirely, or even mainly, of dew, but of drops of water squeezed out from specially large mouths adapted to cope with the quantity of water forced up by the cabbage root. The lady's mantle is a low-growing plant with indented leaves; on the edges drops of water come out and collect at the middle of the leaves. These drops are often mistaken for dew, but it is really water passing out of the plant. The same thing happens with the leaves of grasses, potatoes, nasturtiums (Fig. 53) and other plants. The mouths by which drops of water come out of the leaves are larger than those by which water-vapour alone comes out; they are called water-mouths.

Use of transpiration.—By means of transpiration the plant gets rid of any excess of water absorbed by the root; and the constant current keeps the plant supplied with all the mineral matter needful for its growth and development. As will be shown later, the water is necessary also in order to carry other food material from one part of the plant to another.

Assimilation.—When a plant, grown either in the earth or in a food solution, is analysed chemically, more than half its dry weight is found to be carbon. When a piece of wood is heated to a high temperature, with air excluded to prevent it from burning, charcoal, or nearly pure carbon, is left. No carbon has been supplied to the plant in the food solution, or in the water taken up by the root from the earth; it must, therefore, have some other source of carbon supply.

Air is composed mainly of nitrogen and oxygen, with a small proportion of carbon dioxide, and it is from this last-named gas that the carbon is obtained by plants. Under certain conditions the plant can split up the carbon dioxide, retain the carbon as a tissue builder, and give back the oxygen to the air.

When a piece of water-weed is exposed in a glass of water to bright sunlight, small bubbles of gas form all over it.

These bubbles can be collected by placing a test-tube full of water over the weed. The bubbles of gas rise in the test-tube and force the water downwards (Fig. 54). A strip of glowing wood put into the test-tube, after the tube is taken out of the water, begins to burn again with a flame. This plan is the test for oxygen; and in the present case the oxygen has evidently been produced by the water-weed.

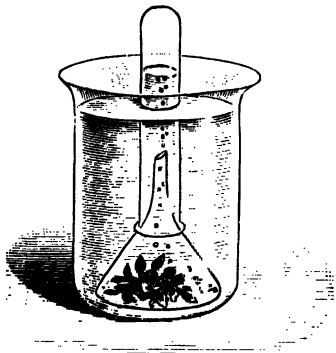


FIG. 54.—Bubbles of oxygen given off in sunlight by water-weed.

If the water-weed be put into a dark cupboard for an hour or two and then taken out, no gas bubbles are seen, nor can any oxygen be collected if a test-tube is put over the weed when it is in the cupboard. Sunshine is necessary for the splitting up of carbon dioxide into oxygen and carbon by plants.

The green parts of the plant make starch out of the carbon obtained from the carbon dioxide in the air and the water taken in by the roots. This process is called **assimilation.** The test for starch has been described already in connection with seeds and roots. But before it can be applied to leaves their green colour must be removed, as it would mask the blue tint due to the effect of iodine on starch if there happened to be any starch in the leaf. Spirits of wine dissolve the substance which gives the green colour to the leaves. The leaf is therefore first warmed in methylated spirit; the spirit becomes green and the leaf pale. The leaf is next washed well in water and put into a dish containing a weak solution of iodine. The blue colour appears first in spots but finally covers the whole leaf, and

this shows that the leaf of a plant that has been exposed to sunlight contains starch.

That sunlight is necessary in the process of assimilation may be shown by covering the leaf of a growing tree with tin-foil and leaving it for at least three days. When it and a neighbouring uncovered leaf are tested, it will be found that in the covered leaf there is no starch, while the uncovered leaf is full of it. This experiment can be tried on any green plant. In plants with variegated leaves starch is formed only in the green parts of the leaves.

FIG. 55.—A green leaf; part of the leaf was covered with tin-foil and exposed to sunlight. Afterwards it was tested for starch by means of a solution of iodine. No colour appeared in the part which had been covered.

The conclusions drawn from these experiments are:

1. Sunshine is necessary in order that a plant may form starch.

2. It is the green part of the leaf which splits up the carbon dioxide of the air.

Sap.—As shown previously, starch does not dissolve freely in water, nor will starch solution pass through the tissues of a plant. Consequently, the starch is turned into a form of sugar; this sugar dissolves in the water brought to the leaves by the water-paths and is carried by another set of pipes into all parts of the plant, where it assists growth and builds up the different parts which make the plant complete—leaves, flowers, fruits, seeds. The current of liquid food is called **sap**. It often tastes sweet, as in the sugar-cane and maple. Sugar is stored up in the fruits of many plants and in the roots of others, as in those of beetroot and carrot.

When starch is stored up as in the tubers of the potato, it is formed from the sap containing sugar; the sap travels

back along the stem to the tuber. The exact changes which take place when carbon dioxide is split up, and its carbon combines with the oxygen and hydrogen in the water brought from the root, are not understood very clearly. It is believed that the first substance produced is sugar. Some of the sugar is carried away from the leaf at once and dissolved in the sap; the rest is turned into starch, which gradually disappears, being re-converted into sugar. When animals eat food containing starch, the saliva in the mouth turns much of the starch into sugar; this change is necessary before the starch can be taken into the tissues of the body.

Assimilation has been described as the most important process in the universe so far as human life is concerned, because on it all animals depend for their food containing carbon, which is one of the chief constituents in the body. No animal can assimilate carbon from the carbon dioxide in the air or from the minerals in the soil. Plants split up carbon dioxide and enable the carbon to combine with oxygen and hydrogen in such a way that animals, which feed on plants, can digest the substance formed and use it for building up tissue and repairing waste in their bodies. People usually eat animal food as well as vegetable, and in this way benefit directly and indirectly from the assimilation carried out by the green parts of the plants.

PRACTICAL WORK.

Examine a cactus. What kind of stem has it? Are there any leaves? If not, what takes the place of leaves? Why are cactuses in England usually grown with their roots in gravel, and seldom watered?

Examine stonecrop and sea holly. What kind of stem and leaves have the stonecrop and sea holly?

In the wheat and Indian corn grown for continued observation, notice the drops of water at the tips of the

opening leaves. At what time of day do these show most distinctly?

Notice a cabbage plant in a garden. Where does the water collect?

Notice a nasturtium plant on a fine morning. Whence come the drops of water on it?

Find a plant of "lady's mantle" in a field or on a hedge-bank. Why is it called "dew-cup"?

Take a primrose leaf. Place the blade in water and blow down the cut end of the stem, either with your mouth or by packing the end of the stem firmly into the nozzle of a bicycle pump, and then pumping air into it. Look at the lower surface of the leaf while the air is being passed along the stem. What happens?

Put a nasturtium leaf into water. Is it wetted all over equally? Try the same experiment with a laurel leaf. Write the explanation of what happens.

Heat a cabbage stalk. What is the black substance produced at first? Why is only white ash left if the burning is continued?

Collect oxygen from water-cress or water-weed as described on page 64. Put a glowing splinter of wood into the oxygen. What happens?

Warm elm leaves in methylated spirit, using great care to prevent the spirit catching alight. What happens to the green colour? Wash the leaves. Write what change takes place when iodine solution is put on the leaves. What does the change show?

Cover a leaf on a growing plant with tin-foil. In three days pick the leaf. Warm it in methylated spirit; wash it. Put iodine solution on it. What happens?

Cut your initials in a piece of tin-foil; then place the foil over a leaf on a growing plant, and try the same experiment as that just described.

These experiments can be carried out successfully on any leaves. Elm, lime, and horse chestnut yield good results. If a tree is in the school grounds, several children can perform the experiment at the same time on different leaves.

Warm a variegated geranium leaf (green, with white patches) in methylated spirit. Wash it. Test it with iodine solution. Where is the starch present in the leaf?

Put a thin layer of vaseline on the lower side of a geranium leaf. Expose it to light. Warm it in methylated spirit; wash it, and test with iodine solution. Is any starch present?

This leaf should be kept in the dark for a few hours before the vaseline is put on it. Why is this necessary?

CHAPTER XII.

RESPIRATION. PROTECTIONS FOR PLANTS.

Respiration.—A gas in the air, called oxygen, is necessary for the life of animals and plants.

When an animal breathes, part of the oxygen in the air which in this way enters its lungs is replaced by carbon dioxide. The way to show the presence of carbon dioxide gas in a mixture of gases is to pass the mixture into lime water, when it makes the lime water look milky owing to chalk being formed.

Plants, like animals, breathe in oxygen from the air and also produce carbon dioxide. Breathing is not so important to plants as to animals; but so long as the plant lives, it needs oxygen for all its parts.

Another name for breathing is **respiration.** In considering plants, a confusion is liable to arise because during the day *assimilation* hides the fact that *respiration* is going on also. In the assimilation of plants the carbon dioxide is *split up*, while in respiration it is *produced.*

Respiration goes on in every part of a plant so long as the plant is alive, and not only in sunlight as is the case in assimilation. Nor does respiration depend on the presence of green colouring matter as assimilation does.

During respiration a plant loses weight; this is because the oxygen of the air unites with the carbon in the plant to form carbon dioxide, which is given off to the air.

Assimilation resembles feeding in animals. The plant gains weight as the result of assimilation.

Production of heat.—Heat is produced by respiration in plants just as it is in animals.

In germinating seeds and opening flowers, respiration goes on very energetically. In certain flowers the heat

FIG. 56.—English elm—showing spreading branches below and shorter ones towards the top.

produced at the moment of the opening of the buds is so great that it can be felt by the finger, and causes a visible rise of the mercury in a thermometer. Some cactus flowers and various kinds of lilies show this warming effect well.

Formation of carbon dioxide.—That germinating peas produce carbon dioxide can be shown by the following experiment. Peas are soaked and placed on damp cotton

wool at the bottom of a flask. The flask is closed and kept warm for two or three days; it is then opened, and a little lime water is shaken up in it. The lime water turns milky, proving that carbon dioxide is present.

It is specially in flowers that respiration goes on rapidly. The large white flowers of the "Madonna lilies" consume five times their volume of oxygen in twenty-four hours.

FIG. 57.—Fir trees; lower branches spreading and turning slightly upward; the upper branches are much shorter.

Passion flowers use up a large amount of oxygen as compared with the amount of carbon dioxide changed by their leaves.

Arrangement of leaves to secure sunshine.—Since its green leaves are so important to a plant as a means of obtaining the greater part of its food, and as this work can be carried on in sunlight only, special arrangements have been developed by which no leaves take away light from another, and no leaf is always in deep shadow.

In plants with *long stems* such as shepherd's purse, mullein, and hawkweed, the leaves nearest to the earth are the longest. Above them the leaves are shorter and shorter, until at the top they are quite small and close to the stem.

In all rosette plants, the upper leaves are much shorter than the lower. In the cases of London pride (Fig. 50) and house-leek this arrangement is well marked. In each of these plants the lower leaves are spade-shaped, with the narrower part of the leaf nearest to the centre of the plant, and consequently shaded by the shorter leaf growing above it, but in the narrow parts of the leaves there is no green colouring matter which is necessary for the splitting up of the carbon dioxide of the air (page 65), so that the failure of sunlight to reach the narrow parts of the leaves does not matter.

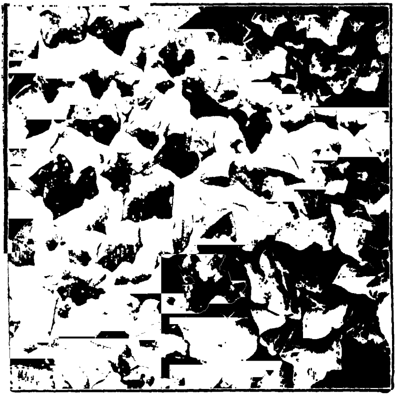


Fig. 58.—Leaf mosaic. Ivy on the side of a house.

In trees and shrubs with abundant leaves, the top branches are vertical, those just below are slanting, those still lower are horizontal, and the lowest of all are often turned earthward. Sometimes the lowest branches of a tree put out twigs which turn upward beyond the shaded part. This arrangement of branches is shown often in firs and in large "puzzle-monkey" trees.

The leaves are arranged on the branches of a plant so as to secure the greatest amount of light and air, and in every kind of tree there are special adaptations for this object.

Large trees have often large, simple, or slightly indented leaves; and smaller plants have either long narrow leaves, as in grasses, or leaves broken into a number of small leaflets, as in ferns, so that they can expose as great a surface as possible and make use of the broken sunlight which filters through to them.

These groupings of leaves are sometimes called **leaf mosaics** (Figs. 58, 59). It is very interesting to make out the plan of them in different plants, and to note how the leaves are arranged for securing light so as not to screen the light from other leaves on the same plant.

FIG. 59.—Leaf mosaic, sycamore.

Sleep of plants.—Many plants have the power of altering the position of their leaves according to the amount of light falling on the surface. Changes in moisture and temperature also influence these movements, which are called **sleep movements.** The main cause of these movements is supposed to be the variation in the amount of light received by the plant at sunrise and sunset. Charles Darwin showed in several kinds of plants that if leaves have not been brightly lighted during the day they do not sleep at night, but, as a rule, leaves take up the night position and day position whether the light varies or not.

The sleep position protects the plant at night against excessive loss of heat from the surfaces exposed. The leaves protect each other by being close together. Charles

Darwin compelled some leaves to remain stretched out during the night and found that they were injured by the cold. Leaves allowed to turn down beside the stem as usual were not hurt.

The sleep position varies in different plants, but the result is always the same. The leaf-blade is turned into such a position that the upper surface is exposed as little as

FIG. 60.—Beans, showing leaves in day position. Photographed at 10.30 a.m. in August on a cloudy day.

FIG. 61.—Beans, showing leaves in "sleep" position. Photographed at 6.30 p.m. in August.

possible. In beans, the leaves turn down parallel to the stem. These leaves are very regular in assuming day and night positions. Even if kept for some days in darkness the leaves assume the sleep position at night-time and rise up in the morning (Figs. 60 and 61).

In the white clover the leaflets rise up and lie face to face. In the wood-sorrel they turn down and lie back to back, close to the stem. A kind of acacia in its sleep position has been described as appearing "at night as if covered with little dangling bits of string instead of leaves" (C. Darwin). The nasturtium leaf turns parallel to the stem. Laurel leaves turn parallel to the stem in very cold weather. This plan protects them from losing too much heat.

Protection devices.—1. Poisonous juices.—In some plants a poisonous sap is present, which protects the leaves, flowers, and fruit against being eaten. Sometimes the sap is a poison which affects some animals only, and not all. The deadly nightshade is fatal to grazing cattle; but a small beetle lives and thrives in great numbers on it, and

rabbits eat it without being poisoned. Probably the poison is to protect the plant against complete extermination, not against slight damage. Thrushes eat nightshade berries and suffer no harm. Colchicum and monk's hood are also poisonous wild flowers. The buttercup and greater celandine have bitter juices and are not eaten by cattle.

Animals also avoid spurges, gentians, mosses, ferns, and succulent plants such as stonecrops and house-leek.

2. **Water.**—Apparently animals dislike eating leaves on which there is standing water. Cattle do not graze freely in the morning but wait till the dew has dried up. The dew-cup or lady's mantle (p. 63) has always drops of water standing on it and is not eaten by cattle or other animals.

3. **Spines, prickles, and hairs.**—Many woody plants have spiny branches and twigs only when young; for example, the sloe. Only the lower part of the holly bears prickly leaves.

Thistles have sharp leaves. Gorse and broom have sharp spines. Borage and comfrey have pointed bristles on the stem and leaves. The nettle has stinging hairs. The mullein has felted woolly hairs, which would be unpleasant in the mouth, consequently the plant is generally left uneaten.

4. **Mimicry.**—The stinging nettle and the dead nettle resemble each other very closely and are often found growing together.

5. **Protection by shelter.**—Some plants, with no special protection, benefit by growing under thorn hedges which afford them shelter and also keep off the attacks of grazing animals. The stitchwort, violet, vetch, and fool's parsley grow in this way. Cattle usually pass over flowers, even sweet-scented ones, although they will eat the green leaves of the same plants readily. This fact is a safeguard against the extermination of the plants. The continuation of the plant

depends on the production of seeds, for which the flowers are essential. The foliage leaves can be spared when the flower has grown and opened, except in bulbous plants and trees. In neither of these cases are the leaves eaten much by cattle.

PRACTICAL WORK.

Blow through a glass tube or straw into lime water. What change takes place in the appearance of the lime water? To what is the change due?

Burn a candle under a glass jar without admitting air while the burning is going on. What happens to the flame?

Put lime water into the jar after taking out the candle. Shake up the lime water. What change do you notice in it?

Put wet blotting paper or cotton wool at the bottom of a glass flask. On the blotting paper place some soaked peas. Close the flask with a plug of cotton wool through which a thermometer is put. The bulb of the thermometer must be among the peas. Observe the changes in temperature which take place as the peas germinate. In two days open the flask. Test the air contained in it with lime water. What happens to the lime water? What do you infer has taken place? If a lighted taper be put into the flask when the flask is opened, it goes out. Why is this?

Draw the arrangement of leaves in the following plants: 1. a branch of elm; 2. a branch of sycamore; 3. a branch of horse chestnut; 4. rosettes of London pride and house-leek; 5. a long-stemmed plant—shepherd's purse, hawk-weed, or mullein; 6. climbing plants—where the leaves are arranged vertically—ivy, Virginian creeper.

Draw from observation the "sleep position" of clover, bean, nasturtium, and wood-sorrel.

Draw the "day position" of the leaves of the same plants.

Collect plants protected: 1. by bitter or poisonous juices; 2. by thorns and spines; 3. by hairs; 4. by growing under the shelter of armed plants.

Draw two examples each of 2. and 3.

CHAPTER XIII.

SPRING FLOWERS.

SNOWDROP. CROCUS. HYACINTH. LESSER CELANDINE.

Spring Flowers.—Most early spring flowers grow from bulbs or corms. Many of them are found wild in woods, as the snowdrop, daffodil, and wild hyacinth or bluebell. The leaves grow to their full size after the flowering time is over.

The reason why these plants can produce flowers so early in the year, before there has been much sunshine, and before the leaves have developed sufficiently to carry on vigorous assimilation, is to be found in the bulbs, corms, or thickened, tuberous, underground stems from which they grow. These underground stems are reserves of food material formed by the leaves of the plants during the previous summer, carried underground and stored up for use in producing the flower next spring. These plants grow often in woods, because the soil, which is composed mainly of decomposing leaves, is soft and specially adapted for them. Light penetrates into the wood and causes the leaves of the bulbous plants to assimilate before the trees have their full foliage.

Snowdrop.—Snowdrops are usually the first flowers to appear. Their French name is "snow-piercers." Sometimes they are called "the fair maids of February," though here and there in a sheltered corner they may be seen in

January. The bulb is small and pointed, and covered with papery scales. When the bulb is cut across, the bud of the flower is seen inside. The leaves are two in number, and one flower arises from each bulb. The flower turns downward.

Parts of the snowdrop flower.—There are six flower leaves. The three outer are white and oval. The inner leaves are square at the top, with a green V-shaped mark on the outside and some green lines on the inner side of each.

There are six stamens, with short stalks and pointed anthers, containing a yellow dust, pollen. In the middle of the flower is the pistil, consisting of stigma, style, and ovary. The flower-leaves and stamens are joined to the ovary, inside which are the tiny, white, future seeds. The flower droops when open, as this position shelters the inside from rain.

After the flowering time is over, the leaves grow rapidly. The result of their assimilation is to prepare food. The food passes downwards and forms new bulbs, which are then ready for next spring. The old bulb is small and soft after the flower has been produced.

The snowdrop belongs to the class of monocotyledons. Its leaves have parallel veins, entire margins, and the parts of the flower are arranged in groups of three. In the seed, there is one seed-leaf and a store of food-material.

Crocus.—Another early spring flower is the crocus. It springs from a corm or swollen underground stem, covered with thin, tough scale leaves, and bearing a bud. Inside the bud are the young leaves and the flower. When the plant grows, it comes above the soil first as a thick, white, blunt point in a papery skin. This point breaks and the leaves, which are slender with a white streak down each, appear. Then the flower comes into sight. There are usually three or four flowers from each corm. The yellow crocus blossoms before the purple and white kinds.

Gerard, an old botanist, says: "It hath flowers of a most perfect, shining yellow colour, seeming afar off to be a hot glowing coal of fire."

Parts of the crocus flower.—Each flower consists of six flower leaves joined to form a long slender tube and divided into six parts at the top, where they expand into the shape of a bell. The flowers open fully in sunshine and close up in cold, dull weather. This arrangement protects the inside.

There are three stamens. The stigma is divided into three parts with fringed edges. The style is very long and the ovary is below the flower leaves. If crocuses are picked, they are broken off usually above the ovary, which is just above the corm. There are three divisions in it, each of which contains unripe seeds.

Crocus seeds ripen at midsummer and should be sown at once if new plants are to be grown from them. The plants raised from seed are not ready to flower for the first two or three years, that is when they have made a substantial corm; and the plant is not often cultivated in this way. The common yellow crocus is a native of Turkey, Greece, and Asia Minor; it has short, slightly branched stigmas. The purple and white varieties are larger, and are found wild in the Alps. They have deep orange, much fringed stigmas. The dried stigmas and stamens are called saffron, which is used for yellow colouring and was formerly much esteemed as medicine. The place Saffron Walden and also Saffron Hill in London were so named because of the crocuses grown there for saffron. "It is reported at Saffron Walden that a pilgrim, proposing to do good to his country, stole a head of saffron and hid the same in his Palmer's staff, which he had made hollow before of purpose, and so he brought the root into this realm with venture of his life; for if he had been taken by the law of the country from whence it came, he had died for the fact" (Hakluyt, *English Voyages*, 1582).

Saffron Hill "was formerly a part of Ely Gardens, and derives it name from the crops of saffron which it bore" (Cunningham).

Pollination.—Anyone who watches a bed of crocuses in spring will notice that butterflies and bumble bees fly from one flower to another and crawl down into the cups of the flowers. They do this in search of honey or pollen, sometimes of both. At the same time that they benefit by gaining their own food, they render a great service to the plant by aiding it in producing seed. Pollen is composed of round rough grains, and these grains cling to the hairy body, legs and head of the bee when it pushes its way into the flower. The stigma has fringed edges and on these the pollen previously gathered by the bee sticks and remains. The transference of pollen from stamens to stigma is called **pollination,** and often it takes place from the stamens of one flower to the stigma of another. This process is **cross-pollination.** When the pollen reaches the stigma of the same flower it is **self-pollination.**

Insects visiting crocuses usually settle on the stigmas first, and this fact secures cross-pollination, because the pollen obtained by the bee from a flower previously visited is brushed off it on the stigma of another flower. As the bee searches in the second flower-tube for honey it takes up a fresh supply of pollen, which it then carries off to a third flower. The insects which have been observed to visit crocuses are common night moths, "Painted Lady" butterflies and bumble bees.

Fertilisation.—When the pollen grains have settled firmly on a stigma they begin to grow. They put out long tubes which make their way down the style to the future seeds. Into the seeds they make a small hole. The contents of the pollen grain enter by this hole and fuse with the inside of the undeveloped seed. This process is

fertilisation. After this fertilisation an increase in size and a development of the seed takes place. The ovary grows and changes; and the seeds eventually ripen. The ripened pistil is the fruit of the plant.

Hyacinth.—The wild hyacinth or bluebell belongs to the class of monocotyledons. It has long leaves, without a leaf-stalk, with straight edges and parallel veins. It grows from a bulb composed of fleshy, overlapping leaves.

Parts of the hyacinth flower.—The flower is bell-shaped. It consists of six flower leaves closely applied together at the lower part and free at the tips. These leaves are arranged in two sets of three.

There are six stamens of which the filaments are united to the lower parts of the flower leaves. Three stamens are longer than the remaining three. In the centre of the flower is the pistil, which consists of the stigma, style, and ovary. The ovary has three divisions and each contains several unripe seeds.

Wild hyacinths are usually blue but occasionally white. "'Dust of sapphire' . . . yes, that is so—each bud more beautiful itself than perfectest jewel" (Ruskin).

Blue and purple flowers are visited by bees and butterflies generally. There is a difference of opinion as to whether there is much free honey in the hyacinth. One botanist says that the insects which visit it bite into the flower leaves for the sake of the sap.

The crocus and hyacinth are, as has been said, monocotyledons, with the parts of their flowers arranged in groups of three or multiples of three. The flower leaves in monocotyledons are not divided into sepals and petals, but are usually alike in shape and in colour. This is not so, however, in the snowdrop. The flower of a monocotyledon is protected generally by a papery, tough bract which sheathes it in the bud. Similar protection is given by the calyx in the flower of a dicotyledon.

Lesser celandine.—In March a plant nearly related to the buttercup is in flower. It is small and low growing, with heart-shaped, smooth green leaves, and thick club-shaped roots. It is the lesser celandine. The flower is bright yellow, with three yellow sepals and several petals, usually nine. Like the buttercup, it is attractive to small beetles which see it from below. Wordsworth speaks of it as

> "Telling tales about the sun
> When we've little warmth or none."

Another common plant belonging to the buttercup family is the *water crowfoot.* In spring, the water crowfoot covers the surface of ponds with small white flowers, each of them resembling a field buttercup except in colour and size. The leaves of the water crowfoot are of two kinds: submerged leaves which are thin and hairlike; and upper leaves which come into the air and are like ordinary divided foliage leaves.

The lesser celandine and water crowfoot are dicotyledons.

Description of any flower.—In describing a flower it is usual to take the parts in a regular order, beginning from the outside. In monocotyledons is stated the number of flower-leaves and whether they are united or separate, and how they are arranged; this, as has been seen, is usually in two groups of three each. In dicotyledons, the sepals and petals are counted, and it is noticed whether all the sepals are alike and all the petals alike, or whether some are different in shape and size from others. If they are alike, the flower is called **regular**; if different, **irregular.**

The stamens are counted, and a note made if they are free, or united either to each other or to the petals in dicotyledons, or to the flower-leaves in monocotyledons. The pistil usually consists of three parts. The stigma is described as simple, divided, or fringed as in the crocus.

When all the parts of the flower except the pistil can be taken away without injuring the ovary, the ovary is called **superior.** When it is of necessity damaged by the removal of the stamens, petals, and sepals it is called **inferior.**

Whether the ovary is superior or inferior must always be stated in a complete description of a flower.

PRACTICAL WORK.

Draw the bulb of the snowdrop. Cut the bulb across and draw it in section.

Draw the corm of the crocus.

Draw a hyacinth bulb after it has been cut across.

Plant snowdrops, crocuses and hyacinths in earth, in a garden, or in flower-pots. Watch the changes in their appearance during a few weeks. What alteration takes place in the snowdrop bud as it opens?

What difference do you notice between crocuses in a garden on a fine day and on a dull day?

Draw the parts of the flower in the snowdrop, crocus and wild hyacinth.

What are the differences between the flower of a wild hyacinth and the flower of a cultivated specimen?

Describe the flowers of each plant under the headings given below.

POINTS TO BE OBSERVED IN DESCRIBING FLOWERS.

1. Whether dicotyledon or monocotyledon.	
2. Protection of buds.	By bract or by calyx.
3. Number of flowers on flower-stalk.	Several or single.
4. Shape of flower.	Regular or irregular.
5. Number and colour of flower-leaves.	Monocotyledons.
Number of sepals. Number of petals.	} Dicotyledons.

Points to be Observed in Describing Flowers—*Continued.*

6. How arranged, if united or free—	
(*a*) Sepals	If hairy or smooth.
(*b*) Petals	If united to form a tube; any special modifications in shape (as in peas, beans, dead nettle and violet).
7. Stamens—	
(*a*) Number.	
(*b*) United to, or separate from, each other.	United filaments or united anthers.
(*c*) It united to flower-leaves, or petals.	
8. Pistil—	
Stigma.	If more than one; if fringed, bent, etc.
Style.	Absent or present; one or more; long or short.
Ovary.	Superior or inferior.
Number of seeds.	Numerous; few; one.
9. Kind of fruit.	Pod; berry, etc.
10. Honey present, or absent, in flower.	At the base of petals (*e.g.* buttercup); in special pouched sepals (wall-flower); in the spur of the petal (violet), etc.
11. Where found most plentifully when wild.	Fields; woods; moors, etc.
12. Time of flowering.	

Note any special points not included above: *e.g.* if the calyx falls off when the flower opens; hairy or sticky flower stem; sweet or unpleasant scent; if insect or wind-pollinated; insect visitors; other flowers similar in structure.

CHAPTER XIV.

SPRING FLOWERS (*Continued*).

HAZEL, BIRCH, ALDER, WILLOW, DOG'S MERCURY.

IN the snowdrop, crocus, and hyacinth, the work of conveying pollen from the stamens of one flower to the stigma of another is done chiefly by bees. The greater number of all flowers are cross-pollinated by insects in this way. Such flowers are specially modified and adapted according to the kind of insect which visits them. The insects which do this work of fertilisation are beetles, moths, wasps, butterflies, hive bees, bumble bees, and flies.

Many trees and plants which flower early are not dependent on insects for fertilisation. They blossom before there are many insects about. In such cases the pollen is carried by the wind.

Flowers of trees.—The flowers of trees are frequently in the form of long catkins composed of stamens. The pistils are in separate flower-heads on the same, or a different tree. Flowers which contain stamens only are called **staminate flowers**, those which have only the pistil are **pistillate flowers**.

Examples of catkin-bearers are the oak, alder, hazel, birch, willow, poplar, and aspen. The flowers are not conspicuous. Willow catkins are the most noticeable and they are visited by bees, in addition to having their pollen carried by the wind.

The **catkins** appear before the leaves and when the spring winds are strongest. This arrangement ensures the free dispersal of the pollen, and its easy access to the pistils of

FIG. 62.—The Hazel; leaf, flowers and fruit.

1. Flowering branch ($\frac{2}{3}$ nat. size).
2. Staminate flower ($\times 2$).
3. A single stamen ($\times 4$).
4. A female flower, cut through the centre.
5. Fruit with husk.
6. Fruit without husk.
7. A foliage leaf.

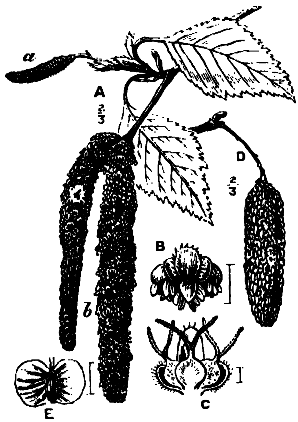


FIG. 63.—Birch.

A. Brand with staminate catkins and pistillate cones.
a. Cone.
b. Catkin.
B. Staminate flower.
C. Pistillate flower.
D. Ripened pistillate cone.
E. Fruit.

the other flowers. Great quantities of pollen are produced and much of it is wasted.

The **pistillate** flowers are smaller than the catkins and are firmly attached to their parent branch; after fertilisation they develop slowly into the fruits which appear later under shelter of the leaves. The fruits ripen and disperse at the end of the summer.

Hazel.—In winter the catkins of the hazel are to be seen on the leafless boughs, as tight, solid, cylindrical masses. They are formed before the leaves fall off in autumn and are

in readiness to open early in the following spring. The catkins expand in February or March. A catkin consists of several flat scales and on each scale is a group of stamens which produce pollen freely.

The pistillate flowers are relatively few in number, as compared with the catkins. They are contained in buds

Photo. Flatters & Garnett, Ltd.

FIG. 64.—Staminate catkins of willow.

covered with dark scales. From the tip of the bud, on a fine sunny day, the stigmas appear as thin red threads. Pollen grains are carried to the stigmas by the wind and stick to them. Pollen tubes pass down the pistil and fertilise the unripe seeds in it. The ripened pistils form the hazel nuts, and the husks of the nuts develop from the bud scales which surrounded the young pistil before fertilisation.

In the hazel, the catkins and the pistillate flowers are on the same tree (Fig. 62).

Alder and birch.—*In the alder and the birch the* stamens are contained in long catkins, which are brownish-red in the alder, and green in the birch. The pistils are in dark brown cones in the alder and in green cones in

Photo. Flatters & Garnett, Ltd.

FIG. 65.—Pistillate catkins of willow.

the birch (Fig. 63). Both catkins and cones are in each case borne on the same tree.

Willow.—In the willow the flowers consisting of stamens are on separate trees from those composed only of pistils. The two are often distinguished as "gold and silver palms," or "ducklings" and "goslings." The stamen-bearing flowers are bright yellow in colour, owing to the pollen. The pistillate flowers are grey-green in colour. The pollen is carried partly by the wind, but the willow flowers are visited

also by great numbers of bees, since they contain much honey *and pollen, flower early, and are conspicuous on the bare boughs. The bees visit them specially in search of pollen, which is used as food and from which, with honey, the* brood-food is made. As many as forty-six kinds of bees and two kinds of wasps have been observed on the flowers of the willow. Flies and beetles also obtain food from the flowers of willows (Figs. 64, 65).

Dog's mercury.—Another wind-fertilised spring flower is dog's mercury, which is a low growing plant found in ditches and near hedges. Its stamen-bearing flowers grow on separate plants from the pistillate ones. The plant grows from a creeping, underground stem, in which was stored up during the previous summer and autumn the reserve food material needful for flowers in early spring. Trees have this reserve food in the woody tissues of their trunk and branches and in the buds formed before the loss of leaves in autumn.

FIG. 66.—Meadow grass; flowers. *A*, flower-spike (natural size). *B*, showing stamens and stigmas.

The staminate flowers of dog's mercury are fixed on slender stalks. Each such flower has three very small green flower leaves, and from nine to twelve stamens.

The pistillate flowers are close to the stem, among leaves. Each has two stigmas and an ovary covered with soft prickles.

Grasses.—Grasses are also fertilised by the wind. The stamens in these plants hang out of the flower on slender filaments. The stigmas are feathery and so adapted to receive the pollen brought to them by the wind (Fig. 66). The pollen of grasses is said to cause hay fever.

Wind-fertilised flowers are inconspicuous in colour and the flower leaves are absent, or very small and insignificant.

PRACTICAL WORK.

Examine the catkins and pistillate flowers of hazel, alder, birch and willow. Draw each of them.

Keep branches bearing catkins in water for several days, note how they open and what large quantities of pollen can be shaken out.

Out of doors, watch willows in flower on a fine day and observe the insects which visit the flowers.

Gather and examine the flowers of dog's mercury. Notice the insignificant appearance and suppression of coloured petals in the flowers. Observe the spreading stigma adapted for easily catching the pollen blown upon it and the ovary covered with soft prickles.

Note the time of flowering and the kinds of flowers. Keep a definite record arranged in tabular form.

Name of tree.	When first observed.	Kind of flowers, and whether staminate and pistillate flowers are on same tree.
Hazel, - - -		
Willow, - - -		
Birch, - - -		
Alder, - - -		
Elm, - - -		
Ash, - - - -		
Sycamore, - -		
Oak, - - -		
Beech, - - -		
Chestnut, - - -		
Walnut, - - -		
Lime, - - -		

CHAPTER XV.

PROTECTION OF POLLEN.

ARUM, VIOLET AND PRIMROSE.

Protection of pollen.—Pollen is protected from rain in most flowers which are fertilised by insects.

In the lime tree, the flowers are covered by the broad foliage leaves when the pollen is ready (Fig. 67). The raindrops roll off the leaves without touching the flower.

In the American balsam, the flowers turn under the leaves when they are ready to open. The edges of the leaf spread out so as to shelter the flower completely, and thus prevent rain from touching the stamens.

$\frac{1}{3}$

FIG. 67.—Lime.

In the globe flower, the flower leaves are all curled over to form a pale yellow ball, from which the flower gets its name. The flowers can be forced open by a bee when it is seeking honey; but raindrops—which are lighter than a bee—roll off without opening the ball. This flower is often self-fertilised.

The crocus, wild rose, marigold, daisy, and dandelion all close up their flowers. This habit shelters the pollen.

When flowers turn towards the ground no rain can enter the flower cup. This arrangement is shown in the lily of the valley, barberry, Herb Robert and harebell.

Arum.—In February or March the shining green leaves of the arum can be found coming up under the shelter of hedges. The leaves are broad and smooth, and they have net veins although the plant is a monocotyledon. The arum is one of the four British exceptions to the rule that monocotyledons have parallel-veined leaves. The other exceptions are Herb Paris, black bryony and arrowhead.

The wild arum has several names; it is called the *spotted arum*, because it has dark spots on its leaves; also *cuckoo pint*, *wake-robin*, *lords and ladies*, and *starchwort.* It grows, as so many early spring flowers do, from a thick underground stem which contains a great deal of starch. Many years ago the arum was grown in the Isle of Portland for the sake of this starch. The starch was called Portland sago.

The flowering part of the arum consists first of a large hood-shaped leaf which overarches a short dark red stalk in the middle (Fig. 68). On the lower part of this stalk are:

1. A ring of hairs, pointing downwards;
2. A band of stamens, purple to crimson in colour;
3. A number of green pistils with ball-like ovaries, and stigmas immediately on the surface of the ovaries.

So each "flower" in the arum is really made up of a number of staminate and a number of pistillate flowers close together. Each stamen and each pistil in itself represents a true flower. Small flies are attracted by the dark red stalk. The flies crawl easily down over the hairs; and, as the pistils are ripe first, the flies leave on the stigmas any pollen which they may have on their bodies if they have been to other arums previously.

After the pistils are thus fertilised the stigmas wither, and a drop of honey appears on each. The flies eat this honey and crawl about inside the flower till the stamens are ripe.

Pollen sticks to the insects' bodies, heads, and legs. Finally the fringe of barrier hairs withers, and the flies escape to wander into other arums and to fertilise them. Sometimes a hundred very small flies have been found in a single arum. It is usually possible to see a few flies crawling about in the bottom of the flower, trying to escape past the hairs.

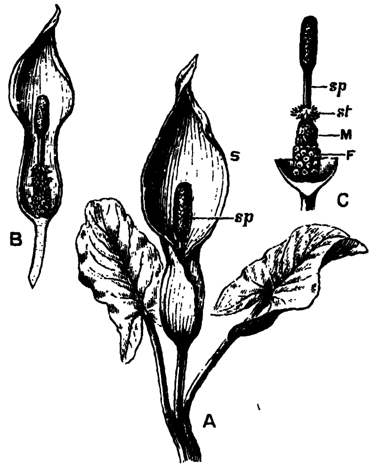


FIG. 68.—Wild arum.

A, flower and leaves, (¼ nat. size); *B*. inside of arum, with part of hood-shaped leaf removed; *C*, *sp*, dark red stalk; *st*, ring of hairs; *M*, stamens; *F*, pistils.

The juice of the arum is very bitter. In the autumn its fruit shows as a short stalk covered with bright scarlet, juicy berries, which are poisonous.

The large white arum lily grown in conservatories belongs to the same family as the spotted arum. It grows wild on the banks of the Nile, and in South Africa.

The violet.—The violet is also a spring flower found under the shelter of hedges or on banks. It differs from the crocus, snowdrop, hyacinth, and arum in being a dicotyledon. It has net-veined, heart-shaped leaves. The flower is irregular in shape and has a green calyx of five sepals, not all the same size, and a corolla of five petals. The two upper petals are like each other, and the two side ones are similar in shape, but the lower petal is larger, has fine lines on it, and differs in shape and size from the other four. The lowest petal is prolonged into a narrow bag or spur, containing honey.

The stamens are five in number and are joined closely together round the pistil.

The two lower stamens have long, club-shaped ends which lie inside the honey bag.

The stigma forms a blunt knob which bends over rather like the beak of a bird. There is a short style ending in the ovary.

The broad lower petal affords a good alighting place for the bees which are seeking honey, and the lines on it have been called honey guides. The bee pushes up the bent stigma, and opens the ring of stamens in trying to reach the honey in the spur. Thus its head or trunk is covered with pollen, which it carries away to the next violet that it visits; there it rubs off some pollen on the stigma before it gets a new supply. In every flower the bee touches the stigma first, and afterwards the stamens. The violet is pollinated by hive bees, and bumble bees—but in this country the pistil seldom ripens and produces seeds. The seeds are developed in small inconspicuous flowers; these are self-fertilised by the pollen from the stamens falling on the stigma and the flower does not open. These seed-bearing flowers appear in autumn and resemble green buds.

The *pansy* or *heartsease*, which is very like the violet, produces seed from its coloured flowers. Its old name is "love in idleness," or "love in vain." This name is said to be still used in Warwickshire. Pansy is derived from "pensée," the French word for "thought." As Ophelia says in *Hamlet*:

> "There is pansies, that's for thoughts."

The *wild heartsease* is usually white or pale yellow with purple markings. It is much smaller than the cultivated pansy. It flowers during the summer, usually in cornfields.

The *sweet violet* is white or blue and flowers in March and April.

The *dog violet* is larger and paler in colour, and has no scent.

Sir Walter Scott calls the violet "the fairest flower in glen, in copse, or forest-dingle."

Violets and primroses flower at about the same time of year and in the same kind of place. For these reasons and because of their beauty and sweetness, they have often been praised together by poets. Henry Vaughan writes:

> "So violets, so doth the primrose fall
> At once the spring's pride and its funeral.
> Such early sweets get off in their still prime
> And stay not here to wear the foil of time;
> While coarser flowers, which none would miss if past
> To scorching summers and cold winters last."

When the primroses are over, spring has ended.

Primrose.—The primrose is regular in its shape, with a single flower on a delicate hairy stalk.

The calyx is green and folded, and consists of five united sepals.

The corolla is made up of five petals united into a long tube within the calyx and spreading out like a round dish, or salver, above. On each petal is a patch of a deeper colour near the top of the tube.

In order to make out the relation of the stamens and pistil it is necessary to examine several flowers. It will then be found that there are two kinds of flowers; one, the **pin-eyed**, in which the top of the tube is nearly filled by a pale green, globular stigma; and the other, the **thrum-eyed**, which has a ring of stamens at the top of the tube. In each kind of flower there are five stamens. The pistil consists of a knoblike, sticky stigma, a long or short style and a round ovary (Fig. 69).

Fertilisation of the primrose.—Honey is produced at the bottom of the tube of the flower, outside the ovary. To reach the honey, long-tongued insects (bees and butterflies)

visit the primrose; and no other insects can get at it down the opening of the narrow corolla. In taking the honey, the bee or butterfly rubs its head or tongue against the anthers and carries off some pollen, which it leaves on the stigma of the next flower visited.

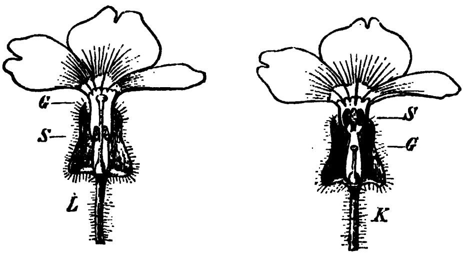


FIG. 69.—Long-styled and short-styled primrose flowers. *G*, stigma; *S*, stamens.

Self-fertilisation is impossible in the pin-eyed primroses as the stigma is above the level of the stamens, but this process can take place in the thrum-eyed variety. The pollen falls from the anthers down on to the stigma; that is, if it has not been carried off by insects as soon as the anther bursts, or if the stigma has not already received pollen from another flower.

PRACTICAL WORK.

Examine the leaves and "flower" of the arum. If possible, keep a plant growing and observe the flies caught in the "flower."

Draw the arum "flower" and leaf.

Examine the flowers and leaves of the violet and write a description of them under the headings previously given (p. 83). Draw the violet leaf and parts of the flower.

Examine the primrose in the same way, paying special

attention to the "long-styled" and "short-styled" flowers. Draw a specimen of each kind of primrose.

Both primroses and violets should be watched growing and unfolding for some weeks, and a record kept of the leaf-buds and flowers—their shape on first appearing and their way of opening, also of their insect visitors.

Find other flowers resembling the violet and primrose in structure. Note their similarities and differences and make a list of flowers examined as shown below:

Resembling the

Violet.	*Primrose*
Dog violet.	Cowslip.
Pansy.	Oxlip.
	Auricula.
	Polyanthus.
	Primula.

CHAPTER XVI.

THE CROSS-SHAPED FLOWERS AND THE PINK FAMILY.

Characteristics of the order.—This group of plants are described as **cruciferous**, or cross-shaped, because the flowers of the plants belonging to it always have four separate petals, slender below and broad above, arranged in the form of a cross.

Some common examples are the wall-flower, stock, charlock, and shepherd's purse.

There are four sepals, separate from each other, and forming the calyx.

There are six stamens, four long and two short. The fruit is a kind of pod, divided in some cases by a partition down the middle, as in the case of *honesty*. Some of the flowers of this order have short, rounded pod fruits as in the case of shepherd's purse. At the bottom of the shorter stamens there are generally two little nectaries; and the honey collects in little pouches at the base of two of the sepals.

Many cruciferous plants are cultivated for food, such as the *cabbage*, *cauliflower*, *mustard*, *turnip*, *radish* and *cress*.

Some cross-shaped flowers are cultivated for their beauty, as the *wall-flower*, *stock* and "snow on the mountain," or *rock cress*. Many grow wild, as the *cuckoo flower*,

shepherd's purse, and *charlock* or *wild mustard*; the last is a very troublesome weed.

The **cuckoo flower**, or lady's smock, flowers in April. It has pale lilac blossoms.

> "When daisies pied and violets blue
> And lady smocks all silver-white,
> And cuckoo-buds of yellow hue
> Do paint the meadows with delight."
> (*Love's Labour Lost.*)

The **shepherd's purse** is a hairy weed with small white flowers and heart-shaped pods as fruit. It flowers all the year round.

Charlock, or **wild mustard**, has bright yellow flowers and is from one to two feet high. It is found often in cornfields and its seeds are scattered shortly before the corn is ripe, so that its continuance in the same field next year is assured.

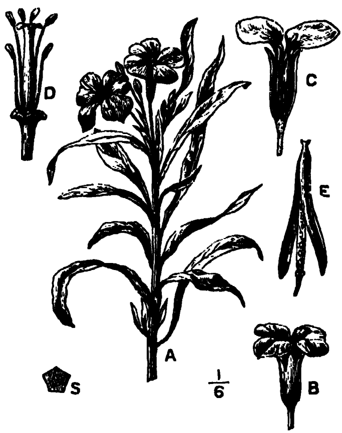


FIG. 70.
A, wall-flower; *B*, single flower; *C*, flower cut open lengthways; *D*, stamens and pistil; *E*, fruit.

The **wall-flower**, which usually is considered as the type of the cross-flower family (Fig. 70), is not a native British plant, but it was naturalised here many centuries ago. It is specially adapted for fertilisation by long-tongued insects. It has stiff sepals, the petals are conspicuous, and the honey glands are at the base of the two short stamens, in front of the pouched sepals. The bee pushes its tongue down to the honey and is dusted with pollen while doing so. The insect rubs this pollen off on

the stigma of the next flower visited, and so causes cross-pollination.

The pink family.—The plants belonging to this group have stems swollen at the places where leaves grow. The leaves are arranged in pairs opposite to each other, have straight edges, and are often grey-green in colour.

The flowers are regular. The calyx consists of four or five sepals, either free or joined into a tube; there are the same number of petals as of sepals, slender below and broader and spreading at the top of the flower. There are usually twice as many stamens as there are petals, though sometimes only the same number.

The pistil has four or five styles and stigmas and a single ovary; it forms a box-like fruit, opening at the top to scatter the seeds when ripe (Fig. 71).

Flowers of the pink family.—Among wild flowers of the pink tribe are *stitchwort*, *chickweed*, *ragged robin*, *red* and *white campions*, *Nottingham catchfly*, *bladder campion*. Garden flowers of this order include the *sweet William*, *pink*, *carnation* and *scarlet lychnis*.

The **stitchwort** is a star-shaped white flower, which grows in hedges and open woodland. It flowers in early summer. It has five sepals, five petals, ten stamens and three styles. The stamens scatter their pollen before the pistil is ready for fertilisation, so that the pollen is conveyed by insects to other flowers in which the pistil is already prepared to receive it. This prevents self-fertilisation (Fig. 71).

In the **red campion** the staminate and pistillate flowers are on different plants. Flies carry pollen from one flower to another. On some of the campions the stems are covered with sticky hairs, which prevent small crawling insects from reaching the flowers, hence their name "catchfly." In these cases the flowers are all adapted for pollination by flying insects; for crawling insects would be of no use to them.

The **Nottingham catchfly** and **evening campion** are visited by moths. During the day their white flowers are collapsed and drooping, but they open towards night and have a sweet

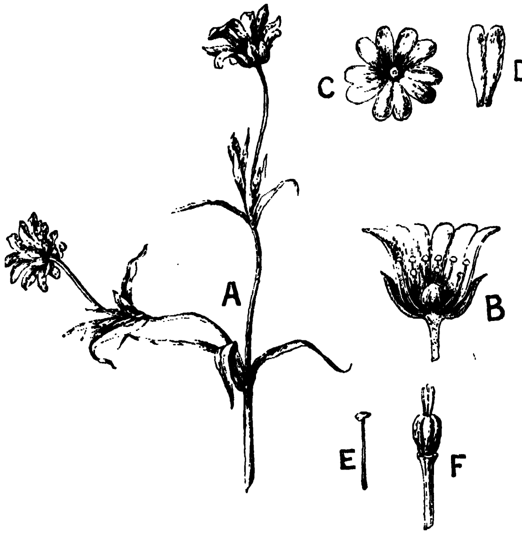


FIG. 71.—Stitchwort.
A, flowers; *B*, flower cut through the middle; *C*, corolla, as seen from above; *D*, petal; *E*, stamen; *F*, pistil (¼ nat. size).

scent. The moths are attracted by the colour and scent. White and pale yellow flowers are usually fertilised by moths. The evening primrose and the tobacco plant are good examples.

PRACTICAL WORK.

Examine the wall-flower, cuckoo flower, and charlock; and describe the parts according to the scheme on p. 83. Draw each flower.

Collect specimens of as many other flowers of the same order growing wild or in gardens in the district. Shepherd's

purse, wild cabbage, garlic mustard, stocks, rock cress and water cress are some of them.

Watch wall-flowers visited by bees on fine days.

Examine the flowers and leaves of stitchwort, pink, red campion, ragged robin and sweet William. Draw them.

Find other plants of the same order. Observe carefully which wild ones have the stamens and pistils on separate plants.

Observe any flower which opens and has a sweet scent at evening, and watch the moths which are attracted by it. Among such flowers are the Nottingham catchfly, evening campion, and—not belonging to this order—evening primrose; and tobacco plant.

CHAPTER XVII.

THE ROSE FAMILY.

INCLUDED in the rose family are many plants cultivated for beautiful flowers and many for useful fruits. The cultivated kinds have all descended from wild varieties.

Characters of the rose family.—Though there are many differences in leaves, flowers, and fruit, the members of the rose family are usually alike in the following points:

In the calyx of nearly all are five sepals. There is often an epicalyx or extra whorl of small green leaves outside the calyx, as in cinquefoil, silver-weed, and other members of the tribe Potentilla.

The corolla consists of five petals of the same size and shape, that is, the flower is regular.

The stamens are numerous, usually more than twelve in number.

The pistil has separate styles and stigmas and is usually superior.

The fruits vary in diameter. We may have a stone fruit (*cherry*, *plum*, *sloe*, *almond*, *peach*, *nectarine*, *apricot*), or a collection of little nuts on, or in, the swollen end of the flower stalk (*strawberry*, *wild rose* hip), or a collection of small stone fruits, (*blackberry* and *raspberry*). (See p. 8.)

In the *apple*, *pear*, *quince* and *medlar*, the fruit is succulent and a horny core contains the seeds.

Blackthorn or sloe.—*One of the earliest of this family to flower in a wild state is the blackthorn or sloe. It is a* hedge shrub, or small tree with spiky branches. In March or April the flowers open before the leaves do. The flowers are small and white; they are very conspicuous against the dark bark from which the tree gets its name of blackthorn, to distinguish it from the *whitethorn*, which is another name for the *hawthorn* or *may*.

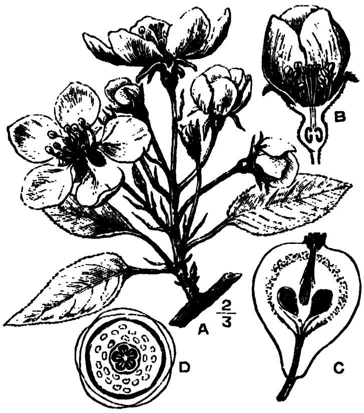


FIG. 72.—Pear.

A, flowering branch; *B*, flower cut across lengthways; *C*, fruit cut across lengthways; *D*, diagram to show arrangement of parts of the flower.

The **hawthorn** or **may** flowers after the leaves have appeared, usually about the middle of May. Its blossoms have a strong scent which attracts flies. The insects touch the stamens and stigmas in searching after honey and so carry pollen from flower to flower. Self-fertilisation also takes place in dull or rainy weather. The flowers in the latter case turn into a slanting position and pollen falls from the stamens on to the stigmas.

The flowers of the **pear, plum, cherry**, and **apple** are alike in the number and arrangement of their sepals, petals and stamens. The apple has pink and white petals.

The pistils of the pear (Fig. 72) and apple have five styles; those of the plum and cherry have but one style (Fig. 73).

The **wild rose** is a characteristic summer flower. It blooms most abundantly in June and July. It is a prickly

tree or shrub and grows in hedges, over which its branches scramble. It has compound leaves with indented or toothed edges. The flowers vary in colour from deep pink to white. They contain no honey. Insects are attracted to them by the large coloured petals and by the sweet scent, and are repaid by pollen. Many of the flowers are cross-fertilised by insects. Self-fertilisation takes place in the

FIG. 73.—Cherry.
1, flowers; 2, flower cut through the middle; 3, fruit cut through the middle.

same way as in the hawthorn. The end of the flower-stalk is expanded to form a disc on which the parts of the flower grow, and below the disc the flower-stalk is urn-shaped. After the flower is fertilised, this urn-shaped end grows rapidly and becomes fleshy. It encloses the ripened true fruits.

Some small plants belonging to the rose family are the *strawberry*, *meadow-sweet*, and *tormentil.* They are included in the same natural order because the essential organs which take part in producing the fruit resemble

those of the rose and hawthorn. The other parts of the flower are also more or less similar in members of the same natural order.

The **wood strawberry** flowers in May and June in woods and under the shelter of hedges. It has white flowers, a calyx bent back, an epicalyx, and bright green leaves in shape like those of the garden strawberry, but smaller.

The rose family contains, as already mentioned, many valuable plants. Although the fruits are wholesome, other parts of some plants of this family contain a deadly poison, which, for example, is found in peach and other kernels of stone fruits, and in the leaves and stem of the cherry laurel. The oil of bitter almonds is very poisonous.

PRACTICAL WORK.

Examine and draw the flowers of the sloe, hawthorn, pear, cherry, plum, wild rose and strawberry.

Draw and describe the parts according to the plan given on p. 83, paying special attention to the arrangement of stamens and stigmas, and to the differences between the flowers of different species.

Make a section with a sharp knife of each flower. Draw the section.

Where are the remains of the flower in the apple, pear, rose hip and haw?

Find other members of the rose family. Mountain ash, Portuguese laurel and cinquefoil are examples.

CHAPTER XVIII.

THE LIPPED OR LABIATE FLOWERS.

General characteristics.—Over two thousand different kinds of plants belong to this natural group. The plants of the lipped class have square stems. The leaves are opposite each other and are scented. The flowers have an irregular corolla. The lower petal is larger than the others and forms a notched lip; and, accordingly, to these flowers the name of **labiates** has been given, from the Latin word for lip. The leaves have numerous little bags containing strongly scented oil in them. Many of the labiates are useful and none are poisonous. Examples are *mint*, *thyme*, *lavender*, *sage*, *peppermint*, *rosemary*, *marjoram*, *ground-ivy*, and *dead nettle.*

Dead nettle.—The dead nettle is one of the commonest British wild flowers. It can be found in blossom nearly all the year round. It grows from a long, creeping, underground stem which sends up flowering branch stems. The leaves resemble those of the stinging nettle, and are an example of protective mimicry (see p. 75). The flowers grow in clusters. The calyx is funnel-shaped and composed of five sepals joined together.

The corolla is irregular. The notched lip petal is just between two sepals. Two small points at the sides represent two other petals and the hood-like petal at the top is really composed of two petals joined together. That is, there are five petals represented in the corolla.

The stamens are four in number and united to the tube of the corolla. Two of the stamens are longer than the other two and are in front. The shorter ones spring from the back. The two anthers of each stamen, which contain the pollen, are at first side by side. They are separated by a thread which connects them when they burst. This thread is called the **connective.**

The pistil has a slender style with a forked stigma and a deeply divided ovary. The ripened pistil divides when ripe into four nutlets or small fruits resembling nuts.

Fertilisation of dead nettle.—The dead nettle is adapted, like all irregular flowers, for fertilisation by insects, and in this case particularly by large bees. Honey is prepared at the base of the ovary, and collects at the bottom of the tube. The corolla points upwards in a slanting direction and is closed by a ring of hairs. The corolla then widens and is parallel to the stem nearer the top of the flower. This arrangement keeps out short tongued insects such as flies and small bees. A bumble bee alights on the lip, pushes its head into the opening of the corolla, and sucks the honey. While the bee is doing this, its body fills up the space between the hood and the lip. Its back rubs against the stamens and collects pollen. The stigma and stamens are often touched by the bee's head as it enters the flower. In this way the bee, as it flies from one plant to another, transfers the pollen. The two little forks of the stigma are ready to take the pollen from the bee's head directly it is pushed under the hood.

Fertilisation of sage.—In the **sage** (Fig. 74) the connectives are very long; only the upper anthers of the stamens under the hood produce pollen. The bee moves the two lower anthers in entering the flower. By so doing the insect causes the upper anthers to swing downward and strike its back, leaving a shower of pollen there. As the bee flies away the stamens spring back under the hood. After the

stamens have ripened in any particular flower the stigma projects forward so that it touches the bee's back just where the pollen has been scattered if the bee has already visited a flower in which the stamens have just ripened.

FIG. 74.—Pollination of the sage by a bumble bee.

1. Flower visited by bumble bee, showing the projection of the curved connective from the hooded upper part of the flower and the scattering of pollen on the back of the bumble bee. 2. Older flower, with connective drawn back and lengthened style. 3. The attachment of the two parts of the anther by the connective (*c*) to the filament (*f*) and the lower half of the anther as disturbed by the bee when it enters in the direction of the arrow. 4. The parts of the stamen at rest before the flower is disturbed by the bee.

PRACTICAL WORK.

Examine a white dead nettle. Draw the stem so as to show its shape. Draw the leaves so as to show their shape and arrangement on the stem. Draw the parts of the flower.

Why is it easier for a bumble bee to fertilise the flower of the dead nettle than for a small fly to do so? Why is this plant called "dead nettle"?

Collect other labiate flowers—the archangel, mint and thyme for instance. Draw the parts of the flower in ground-ivy, lavender and sage.

Watch bees visiting a bed of thyme, and describe what you observe.

Watch a bee on a sage blossom, and describe what you observe.

Collect leaves which are scented. Make a list of those which belong to the labiate family.

CHAPTER XIX.

PEAS AND BEANS, AND THEIR RELATIVES.

THE pea family belongs to a very large natural group; there is great variety in the arrangement of flowers, and in the size and shape of the plants. The British members of the pea family are, however, of one general type. The flowers are irregular, somewhat resembling a butterfly in form, and the fruits are pods. It is called the **pod-bearing** or **leguminous order.**

The flower of pod-bearers.—The calyx has five projections; and this shows that the calyx represents five sepals.

The corolla has five petals; the uppermost is called the **standard**; the two side petals are called **wings,** and enclose the two lowest; the two lowest petals are joined at their lower edges, and form the **keel**, so-called because it looks like the keel of a boat seen sideways.

There are ten stamens, either with their filaments united into a tube, or with nine filaments united and one stamen standing free.

The pistil consists of a single stigma, style and ovary.

The fruit is a pod.

Examples of leguminous food plants used by man and animals are *peas*, *beans*, *vetches*, *lentils* and *clover.*

Other members of the leguminous order are: the *bird's-foot trefoil*, *furze*, *broom*, *laburnum* and *acacia* (*robinia*).

Common pea.—The common pea belongs to the guild of climbers. It has compound, net-veined leaves, with large outgrowths where they leave the stem. It climbs by tendrils.

The calyx and corolla consist of the parts mentioned under the general description of the family (p. 110).

The stamens are arranged in a group of nine joined together and one separate. The wings and keel are interlocked by means of projections of the wings fitting into depressions in the side of the keel.

Fertilisation of the pea.—The opening made as a result of the natural arrangement that one stamen is free from the others allows the honey to be reached by a visiting insect. The pea in this climate is frequently self-fertilised owing to the bending of the stigma; but it is also visited by bees, which are strong enough to push aside the stamen and get the honey. The bee is dusted by the stamens and carries away pollen. The stamens and pistil resume their original position after the bee has gone; and the flower is visited repeatedly by insects.

Fertilisation of gorse.—The gorse has large, yellow, honeyless flowers. The stamens are ten in number, all united together to form a tube; and as they ripen, the pollen falls into the keel and collects there. When an insect alights on the flower, it presses down the two wing petals. The flower explodes, thus dusting the visitor with pollen. The bee flies away and conveys the pollen to the stigma of another flower. The bee also uses some of the pollen as food. Bumble and hive bees cause the gorse flower to explode. The flower remains collapsed, but is visited by smaller bees and flies which eat the pollen left behind, although they are not strong enough to open the flower for themselves. As there is no honey, there is no need for an opening in the tube of stamens to allow the insects to reach the bottom of the flower.

Fertilisation of clover.—Clover is very rich in honey. The flowers are small and several together form a head. Each small flower is composed of the same parts as a pea flower. Red clover is adapted specially for fertilisation by bumble bees. Its seeds cannot set if there are no bumble bees to visit the flower. The petals unite to form a deep tube and the stamens are joined to it, so that the bumble bee in securing honey also dusts himself with pollen, which he conveys to other flower heads. The hive bee has not a tongue long enough to reach down the tube of the flower to the honey and stamen.

Subterranean clover.—The subterranean clover has two kinds of flower-heads. After fertilisation, one kind of flower-head turns downward. On each such head a few flower buds do not open when the rest of the flowers blossom. These undeveloped flowers grow into green fingers after the rest of the flowers have formed seeds, and push a way into the soil so that the pods may be protected from grazing sheep. The fruits formed from these flower-heads ripen under the ground. There are only two or three pods on each head of subterranean clover. This clover has creamy white flowers, and the whole plant is covered with hairs.

The cultivated **white** or **Dutch clover** is fertilised by hive bees. After fertilisation, the flowers all turn downwards.

The **bird's-foot trefoil** is a common field plant; it has smooth leaves; its stem lies close to the ground. The flowers are deep golden yellow in colour. The blossoming time is July and August. When the pods are ripe they stand out from the stalk rather like the toes on a bird's foot. There are from three to ten flowers on a stalk. The pollen from the ripened anthers collects in the keel before the petals are full grown. The stamens keep the pollen in place in the keel although their anthers have withered. The pistil grows up through the mass of pollen. When

a bee descends on the flower, it pushes down the wings and keel and so pollen is forced on to its body. If it now visits another flower, the stigma rubs against the pollen-covered part of the bee and so is fertilised (Fig. 75).

FIG. 75.—Bird's-foot Trefoil.
1, flowering branch; 2, flower; 3, pistil and stamens; 4, carpel; 5, fruit; 6, corolla; *a*, standard; *b*, wings; *c*, keel.

PRACTICAL WORK.

Look at the stem, leaves and tendrils of the pea. Draw a leaf, showing where it is joined to the stem. Does the pea climb in the same way as the scarlet runner bean? If not, what is the difference?

Draw the separate petals of a pea flower. How are the wings fastened to the keel? Draw the arrangement.

Write a full description of the pea according to the scheme on p. 83.

Draw the flower of the scarlet runner bean.

Some flowers of the pea and of the bean have holes at the bottom piercing the petals. What causes these holes?

Look at the flower of the gorse before and after a bee has visited it. What difference is there?

Watch a bee settling on a gorse flower. What happens?

Find other plants of the pod-bearing order. Make a list of their resemblances and differences. The bird's-foot trefoil, purple, red, and white clover, lucerne, subterranean clover, laburnum, vetch and lupin are familiar examples.

CHAPTER XX.

THE COMPOSITE FAMILY.

WHEN a daisy, or dandelion, is looked at carefully, it is seen to differ very greatly from such flowers as the violet, primrose, or wall-flower. Each flower is composed of a number of very small flowers, called **florets**. The florets grow close together. They are supported by a disc and a number of green **bracts**, something like small leaves.

Dandelion.—In the dandelion the florets are alike in colour and shape.

The calyx of each floret is a ring of silky hairs; it is called the **pappus**.

The corolla is a tube inside the pappus; at the top it spreads out on one side like a strap. The strap ends in five little teeth. This shape shows that the corolla is formed from five petals joined together.

There are five stamens which grow from the tube of the corolla. The anthers containing pollen are very long and joined to each other to form a cylinder.

The style of the pistil pushes its way up through this cylinder and so sweeps the pollen towards the top. This action causes the pollen to fall upon other florets and fertilise them. Some pollen is carried to other heads of florets by bees.

After the style has reached the top, the two stigmas turn outward. No pollen from the same floret reaches them, since they are pressed closely together until they are well above the level of the top of the stamens.

The ovary is inferior. (Compare p. 83.) After fertilisation and the ripening of the fruit, the short stalk between the ovary and the pappus grows much longer. The pappus spreads out and forms a flying machine by which the fruit is carried far from the parent plant. It belongs to the winged fruits (p. 10). The head of ripened dandelion fruits is well-known as a **blowaway**. It is a favourite game to try to scatter all the little winged fruits by blowing on them. The dandelion is adapted both for insect fertilisation and for the self-fertilisation of neighbouring florets, if insect visitors fail; but as it has a bright colour and abundant honey this is not likely to happen. Ninety-three kinds of insects have been observed taking honey and pollen from dandelions.

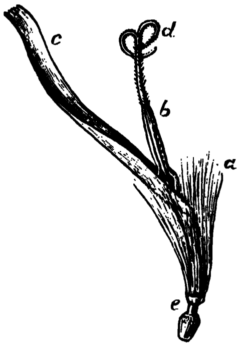


FIG. 76.—Floret of dandelion.
a, pappus; *b*, anthers; *c*, corolla; *d*, stigma; *e*, ovary.

Thistle.—The thistle is a composite flower. The florets of each head are regular in shape. They are small tubes with five-toothed edges. The stamens and pistil are like those of the dandelion.

Daisy.—The daisy head is formed of the two kinds of florets—strap-shaped and tubular. The ring of white florets on the outside is to attract insects by making the flower conspicuous. These florets have no calyx. They have strap-shaped corollas, with three points to the strap, indicating three petals. They have no stamens, but there is a pistil with a divided stigma. The outer white florets are called **ray florets**. The yellow florets are called **disc florets**; these have no calyx, but they have a regular tubular corolla, five stamens, and a pistil.

Marigold.—In the garden marigold the ray florets are

like those of the daisy; they have no stamens; the disc florets, however, have stamens only with a style and globular stigma. The stigma is of use to push the pollen upward out of the tube.

Cornflower.—In the cornflower, the florets are all tubular like those of the thistle. The outside florets are much larger than the rest and have no stamens or pistil. Their work is to make the flowers conspicuous and so to attract insect visitors.

General characteristics of the order.—The composite plants are found in all parts of the world, and many of them are very common. The flowers are always arranged in heads surrounded by bracts. These bracts turn up and protect the florets from cold and damp. This closing of the heads is very regular in the daisy, dandelion, yellow goat's beard ("Jack go to bed at noon") and other wild flowers.

The fruits are always one-seeded, with a tough skin. Often each has a pappus for dispersing it. A great number of this order are cultivated as garden plants; the *dahlia*, *aster*, *marigold*, *southernwood*, *chrysanthemum*, and *sunflower* are examples. Some are grown for food, like the *artichoke* (both kinds), *salsify*, *endive*, *chicory*, and *lettuce*. Some of them are bitter. Tonic medicines are prepared from some, such as the *dandelion*, *chamomile*, and *tansy*.

The different kinds of wild flowers which are composites are almost too numerous to mention. Among the most widely distributed are the *daisy*, *dandelion*, *thistle*, *hawkweed*, *goat's beard*, *yarrow* and *knapweed*.

Of the wild flowers the daisy has always been the favourite of poets, from Chaucer to Tennyson. Chaucer says:

> "Of all the floures in the mede
> Then love I most those floures white and redde,
> Such that men call daisies in our town."

and

> "The Daisie, or else the eye of the Day,
> The Empresse and floure of floures all."

Of modern poets, Burns, Wordsworth and Tennyson have praised the daisy. In England it is in flower somewhere or other all the year round. It grows everywhere in Europe, is scarce in North America, is found in North Africa, but not in Asia, Australia, or any tropical countries (Ellacombe).

PRACTICAL WORK.

Examine the flower head of the dandelion. Take off the bracts and observe their shape and texture.

Draw both the flower head and a separate floret. Notice the pappus of hairs, the strap-shaped corolla with five small points, the ring of stamens, and the forked stigma.

Find and draw florets showing different stages of growth of the stigma.

Examine and draw the tubular florets of the thistle.

Examine and draw a ray floret of the daisy.

Draw a disc floret. What are the differences between ray and disc florets?

How does a tubular floret of the daisy differ from a tubular floret of the dandelion? Keep a sunflower in water for several days. Draw the florets in different stages. What is the fruit of the sunflower?

CHAPTER XXI.

SOME COMMON FOREST TREES.

THE OAK, BEECH, ELM, AND BIRCH.

TREES usually live for many years. They have thick, woody stems called **trunks** or **boles**, covered with bark. The bark is dry and protects the inside of the stem from injury. There is a layer of cork between the bark and the wood of the tree-trunk, and this cork prevents water passing from the wood into the bark. The appearance of a piece of wood from a tree-trunk which has been cut across is described on p. 35 and shown in Fig. 34. Tennyson refers in the *Princess* to "huge trees, a thousand rings of Spring in every bole."

The Oak.—The oak is a long-lived, slow-growing tree. It has been reverenced by many nations; the Romans, for instance, gave a crown of oak-leaves as a reward for great bravery. "Gospel oaks" in different parts of England were so called because open-air preaching took place under them. The bole of the oak is very thick just above the ground and the tree has usually thick twisted branches. The bark is rugged and has furrows on it. The roots are less liable to rot than are the roots of many other trees.

It is said that the builder of the first Eddystone Lighthouse obtained his original idea of the best shape for the lighthouse from observing the proportions of an oak-trunk.

The oak does not generally grow to a great height. The leaves of the oak are longer than they are broad, and have wavy edges. The leaves and the flowers open at about the same time in April. The stamens and the pistil are in separate flower-heads. The staminate flowers are in long drooping catkins. The pistillate flowers are small; each one has a scaly little cup at its base; this cup grows after-

FIG. 77.—The Oak.

wards into the cup of the acorn, which is the fruit of the oak-tree.

There are often some curious growths on the oak which are sometimes mistaken for a kind of fruit and are called **oak-apples** or **oak-galls.** Oak-apples are caused by a small fly, known as a gall-fly, which makes a small hole in a twig and lays one or two very small eggs in the hole so formed. After this injury, a covering, called a **gall**, which is formed from the sap of the oak, grows over the egg. Galls are of many different kinds, though probably

the best known are the oak-apples formed on twigs of the oak. Another kind of fly lays its eggs in the catkins of staminate flowers. The galls formed in this case are like green currants in shape and size.

Two varieties of oak are grown in England. The kind described here is the common, or English, oak. Oaks grow well in warm sunny places, in deep soil, where plenty of moisture reaches the roots. Clay and marshy soils suit the English oak best.

FIG. 78.—The Oak; leaves, flowers and fruit.

A, flowering branch; *B*, a staminate flower; *C*, stamens (magnified); *D*, a pistillate flower (magnified); *E*, acorns; *F*, cup of acorn; *G*, *H*, seed.

The wood of the oak is hard and tough; it is used for engineering structures and ship-building; and by wheel-wrights, coopers, and cabinet-makers. Oak bark is used in the tanning of leather.

Oak timber is very durable. Some of the oak doors in Westminster Abbey are said to be more than twelve hundred years old; and the oaken shrine of King Edward the Confessor is known to be over eight hundred years old.

The poet Pope says, referring to the ships of English oak:

> "Let India boast her plants, nor envy we
> The weeping amber and the balmy tree
> While by our oaks the precious loads are borne
> And realms commanded which those trees adorn."

The Beech.—The beech is found in most parts of England. It is usually a tall tree with smooth bark. In summer it is very full of broad leafy foliage, so that it casts a thick shadow on the ground beneath its spreading

branches. The boles of beeches are straight and resemble columns.

The leaves are thin and smooth; and when they first open are of a very delicate green colour, which later

FIG. 79.—The Beech.

becomes darker. The leaf-buds are long and pointed; they are covered with smooth light brown bud scales, which fall off when the leaf unfolds.

The flowers are of two kinds, as in the oak, alder, birch, and hazel (Chap. XIV.). The staminate flowers are arranged in globe-shaped heads; each flower consists of several

stamens. The pistillate flowers consist of small heads each containing two flowers. These flowers after fertilisation produce the **fruits**, which are three-sided nuts. A woody husk, at first somewhat resembling the cup of the acorn, grows round the nuts; but the husk becomes much larger and bristly, and covers the nuts entirely till they are ripe; then it splits and the nuts fall out. Squirrels often store beech nuts for food during the winter.

Beech trees grow most abundantly in climates where there is no severe or long-continued winter cold. They prefer a moist soil containing a considerable amount of lime mixed with clay. The beech thrives best in places which look to the east or north-east; on account of its smooth bark it is apt to suffer from scorching or sunburn if it is exposed to a west or south-west aspect.

FIG. 80.—The Beech.

A, flowering branch; *B*, a staminate flower (×4); *C*, pistillate flower cut through lengthways; *D*, ovary cut across; *E*, cup and fruits; *F*, fruit.

There are some well-known groups of beeches near London at Burnham Beeches and Knockholt Beeches.

The drip from beech trees, as well as the thick shade cast by the trees, are unfavourable to the growth on the ground in beech woods of any plants except young beech seedlings.

The timber of the beech is used for making furniture, for wood-turning, and for the scabbards of swords, since it

can be cut into thin plates. Woodworking toolmakers also employ beechwood in their trade, and wooden shoes worn by the French and Dutch peasants are made of beechwood because it does not absorb water and wears well. John Evelyn, a great English writer, says of beeches, "They

FIG. 81.—The Elm.

make spreading trees and noble shade." Gilbert White, who wrote the famous book, *The Natural History of Selborne*, calls the beech "the most lovely of all forest trees, whether we consider its smooth rind or bark, its glossy foliage or graceful, pendulous boughs."

The Elm.—Elms are usually tall trees, with straight trunks and rough bark.

The leaves are hairy, ovate in shape, but with one edge

more curved than the other; the edges are toothed. The leaves open in April after the flowering time is over. The elm has small purplish-red flowers which open in March or early April. Each flower consists of five flower-leaves joined together in a small bell, and has five stamens and two styles. The fruits, which are winged nuts, do not always ripen; they are pale green, thin and expanded, with the seed in the middle.

New elm plants often arise from creeping shoots put out from the lowest part of the bole of a large elm.

It is supposed that the English or small-leaved elm (Fig. 56) was introduced into England originally by the Romans. The mountain, Scots, or wych elm (Fig. 81) is a native of Britain and Ireland; but elms generally are more abundant in Southern than in Northern Europe. They grow more frequently in France, Spain, and Italy, than in Germany and Switzerland, and more frequently in the south of England than in Scotland or Norway. The wych elm is the only kind which is more abundant in Scotland than in England.

FIG. 82.—The Elm; leaves, flower and fruit.

1, flowering branch; 2, branch with leaves; 3, a flower (×2); 4, a flower cut lengthways; 5, a fruit.

Elms flourish best in a mild climate and in damp warm places where there is good fertile soil, as in valleys and at the foot of hills. These trees are often injured by severe winters. The wood of elms is hard and is used in building houses and ships. For building purposes the tree is generally cut down when it is between a hundred and a

hundred and thirty years old. There are several varieties of elm.

The Birch.—The birch grows most plentifully in Northern Europe, where it forms beautiful woods. It is

FIG. 83.—The Birch.

a hardy tree and grows well in exposed situations and also on poor soil, or where only a thin layer of soil covers the hard rock beneath. The tree has a very slender stem and branches, thin small quivering leaves (p. 51) and silvery grey bark, with black and brown patches.

The bark is very tough and strong and is used in Sweden

as the covering for roofs, instead of tiles or slates. It is also used for making shoes, leggings, and canoes. This last use is described in Longfellow's poem of *Hiawatha* :

"Give me of your bark, O Birch Tree,
Of your yellow bark, O Birch Tree!
Growing by the rushing river,
Tall and stately in the valley!
I a light canoe will build me."

The flowers of the birch are described on p. 86. The fruits are small winged nuts. The wood of the birch is used largely by cabinetmakers and wood-turners; and also for making wooden shoes or sabots, tubs and casks, and the felloes of wheels. Birch twigs are made into brooms, and an old writer, Gerarde, quaintly says: "Schoolmasters and parents do terrify their children with rods made of birch."

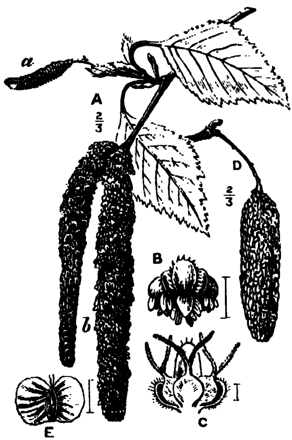


FIG. 84.—Birch.

a, cone; *b*, catkin; *A*, branch with leaves, catkins, and cone; *B*, staminate flower; *C*, pistillate flower; *D*, ripe cone; *E*, fruit.

PRACTICAL WORK.

Collect specimens of the leaves, bark, and flowers of the oak, beech, elm, and birch.

If possible obtain a specimen of the wood of each tree. Notice the rings showing in the wood. What causes these? Draw the shape of a leaf of each tree.

Which tree has the smoothest bark? Which tree has the roughest leaves? What other plants have hairy leaves?

CHAPTER XXII.

EPIPHYTES. PARASITES. SAPROPHYTES. INSECTIVOROUS PLANTS.

One group of plants which are partially dependent on other plants has already been considered—the weak-stemmed or climbing plants. The other groups or guilds of dependent plants are **epiphytes, parasites** and **saprophytes.**

Fig. 85.—Orchid growing as epiphyte on the branch of a tree.

Epiphytes.—The epiphytes, or "perched plants," germinate on other plants, and grow without feeding on their **host,** as the plant on which the epiphyte grows is called. The epiphytes receive lodging but not food. The chief danger which threatens these plants is lack of water, consequently they are found where long-continued drought is unknown. In temperate climates, mosses and lichens are the chief representatives. The greater number of epiphytes are found in tropical forests where there is plenty of moisture. They are adapted specially for absorbing water from rain and from the moist air surrounding them. Their green leaves provide them with the carbon needed to form their tissues. Many of the orchids

captivity. It thrives better with a diet of meat in moderation than if left only to assimilate carbon from the air.

Butterwort.—The butterwort has a rosette of greenish yellow leaves which are very sticky and slightly concave. When a small fly settles on the leaf, the edges curl up and hold it fast. The sticky fluid then kills and digests the fly.

Photo. Flatters & Garnett, Ltd.
FIG. 88.—Butterwort.

The leaves of the butterwort have the power of curdling milk, an effect due to this digestive fluid. The blue flowers of the butterwort contain honey and attract bees as fertilisers, but they have no power to kill and digest small flies, such as is possessed by the leaves. Bees are not hurt by the butterwort leaves (Fig. 88).

Pitcher plants.—In pitcher plants some of the leaves are formed into the shape of pitchers. On the rim of the pitcher, honey is produced which attracts the insects. The insects slip into the trap over a barrier of hairs all pointing downward, and the hairs effectually prevent them getting out again. The pitcher is filled partly with water containing a digestive liquid, so that the insects are digested and partly absorbed into the tissues of the plant (Fig. 89).

FIG. 89.—Pitcher-leaf with part removed to show the fluid inside (*F*).

In the common teasel the leaves arise opposite to each

other. Each pair is united to form a basin which holds water round the stem. Very probably some of the water is absorbed by the plant. Mr. Francis Darwin thinks that these basins serve as traps in which insects are caught and digested. Another opinion is that, as the teasel is fertilised by flying insects, it needs protection against crawling animals such as snails, and that this protection is given by the moats of water surrounding the stalk.

QUESTIONS AND EXERCISES.

C.L.J. = Cambridge Local Junior Examination.
C.L.P. = Cambridge Local Preliminary Examination.
N.F.U.P. = National Froebel Union Preliminary Examination.
B.E. = Board of Education Examination. Stage I.

CHAPTER I.

1. Write a careful description of the flower of the buttercup, and draw the different parts.

2. What are the essential parts of a flower? (N.F.U.P.)

3. Describe and draw the roots of the buttercup and of the dandelion.

4. Name three common kinds of buttercup, and state the reason for the name used to distinguish each kind.

CHAPTER II.

5. Of what use to a plant is its fruit? Mention any two fruits which you have examined, and make drawings of them. (C.L.P.)

6. What are the chief classes into which fruits are divided? Give two examples of each kind.

7. Write a short account, illustrating your answer by sketches, of the mode of scattering the seeds to be seen in any three *capsular* fruits you may choose. (B.E.)

8. Describe and draw the fruit of the hogweed, the elm, the apple and the strawberry.

CHAPTER III.

9. Give a short account of some of the ways in which seeds are dispersed.

10. What kind of seeds are dispersed by the wind? (N.F.U.P.)

11. How are the seeds of the following plants dispersed: violet, willow-herb, wood-avens, gorse?

12. Name some fruits which are attractive to birds or other animals. How are the seeds in these fruits protected against being eaten or digested?

CHAPTER IV.

13. Describe and draw the parts of a bean-seed and of a grain of maize.

14. What changes take place in a seed when it begins to germinate?

15. How do you distinguish between a seed and a fruit? Give two examples of each. (C.L.P.)

16. Explain the following words: life-history, embryo, cotyledon, radicle, plumule.

CHAPTER V.

17. Describe exactly how you would arrange to grow some beans in order to watch all the stages of germination. Illustrate your answer by drawings. (B.E.)

18. Describe as fully as you can what happens when a seedling bean is placed on its side and is allowed to go on growing. (B.E.)

19. What are the different kinds of roots?

20. In what ways may the root be of use to a plant? Give an example of each.

CHAPTER VI.

21. How does the stem appear first (*a*) in the germinating seed of the French bean and (*b*) of the pea. What change takes place in the cotyledons during germination?

22. How can you distinguish a stem from a root? (B.E.)

23. Describe the flower stalk of the tulip and the stems of the everlasting pea, sedge, briar-rose, oak, poppy and furze.

24. Mention any three climbing plants which grow wild in England, and explain in each case how and why the plant climbs.

CHAPTER VII.

25. How does an underground stem differ from a root? Give some examples of underground stems.

26. Mention two plants that possess bulbs. Describe the structure of the bulb of one of them.

27. What is a corm, and in what ways does it differ from a tuber and from a bulb?

28. What practical use has been made of plants with "creeping stems"? Name two plants which produce creeping stems.

CHAPTER VIII.

29. What causes the fall of the leaves from trees in Autumn?

30. What can be seen inside a large bud of horse chestnut?

31. Write a short account of winter buds.

32. Describe some of the ways in which leaves are arranged in the bud.

CHAPTER IX.

33. What different kinds of leaves may occur on a plant?

34. What are the uses of the leaves which are not foliage leaves?

35. Write a short account of the ways in which leaves are arranged to resist injury by wind, snow and rain.

36. Give examples of parallel-veined and of net-veined leaves, with drawings.

CHAPTER X.

37. How would you prove that plants give off water vapour?

38. By what means does a plant make up for the loss of water by transpiration? Where does the water come from?

39. What substances are present in water absorbed by the roots of a plant from the earth? What happens if the plant is not supplied with these substances?

40. What are the "veins" of a leaf? What are their uses? How can their uses be shown by experiment? (B.E.)

CHAPTER XI.

41. Write a short account of the ways in which plants are protected against excess of water on their leaves; and the ways in which they are adapted for living in dry or damp places.

42. Plants are said "to starve in the absence of sunlight." Explain this statement. (B.E.)

43. For what purpose does a plant spread its leaves to the light and air? (C.L.P.)

44. In what way is the presence of carbon dioxide in the air of importance to green plants? (C.L.P.)

CHAPTER XII.

45. How would you show that plants cause changes in the air surrounding them? (C.L.P.)

46. What are "sleep movements"? Describe these movements in any two plants that you have seen. (B.E.)

47. Describe the different ways in which plants are protected against being eaten by animals.

48. How are leaves arranged so as to secure the greatest amount of sunshine? Why is this necessary?

CHAPTER XIII.

49. How is it that the snowdrop, daffodil and wild hyacinth can produce flowers early in the year? What is the advantage to these flowers of growing in woods?

50. Write a short account of the crocus.

51. If you were given a flowering plant, how would you proceed to find out whether it was a dicotyledon or a monocotyledon? (C.L.J.)

52. Describe the lesser celandine and water crowfoot.

CHAPTER XIV.

53. What is meant by wind fertilisation? When do wind fertilised plants usually flower? Give examples. (N.F.U.P.)

54. Describe the flowers of the hazel.

55. Describe the flowers of the willow. How do they differ from the flowers of the alder and the birch?

56. What is "dog's mercury"? When does it flower? How does a wind fertilised flower differ in appearance from a flower fertilised by means of insect visitors?

CHAPTER XV.

57. How is the pollen protected from rain in the following flowers: lime tree, globe flower, snowdrop, harebell, wild rose and dandelion?

58. Write an account of the wild arum.

59. How is the flower of the violet adapted for the visits of bees? Where are the seeds of the violet formed?

60. Describe as fully as you can the parts of the flower of the primrose, and the way in which it is fertilised.

CHAPTER XVI.

61. Why are the cross-shaped flowers so named? Give six examples of flowers belonging to this order.

62. Describe the parts of the flower of the wall-flower.

63. Explain the way in which insects are of use to flowers, and the means by which flowers attract them. (B.E.)

64. Describe the stitchwort. What other wild flowers belong to the same family as the stitchwort?

CHAPTER XVII.

65. In what points are the members of the rose family usually alike?

66. Why is the black-thorn so called? What is the white-thorn?

67. How is the hawthorn fertilised?

68. Describe the wild rose and the wood strawberry.

CHAPTER XVIII.

69. What are the general characteristics of labiate flowers?

70. How is the flower of the sage fertilised?

71. Describe the arrangement of the stamens in the dead-nettle.

72. Name some common labiate flowers. Which of them are useful to man?

CHAPTER XIX.

73. Describe and draw the parts of the flower of the pea. How is the pea fertilised?

74. Explain what happens when the flower of the gorse is visited by a large bee.

75. Describe the red, the subterranean, and the Dutch, clover.

76. Write a description of the bird's-foot trefoil, and explain why it is so called.

CHAPTER XX.

77. How does the dandelion differ from the wall-flower? Describe the dandelion fully.

78. Compare the flowers of the dandelion, thistle and corn-flower.

79. Describe, with sketches, the structure of a daisy.

80. What are the general characteristics of the composite order? Name some of the order which are used for food, and others which are found growing wild.

CHAPTER XXI.

81. Describe and draw the leaves, flower and fruit of the English oak.

82. What advantage is there to the elm and the birch in flowering before their leaves open? Name some other trees of which the flowers appear after the leaves.

83. Write a short account of the elm.

84. What use is made of the wood of the oak, beech and birch? In what kind of soil does each of these trees grow most luxuriantly?

CHAPTER XXII.

85. What are epiphytes, parasites and saprophytes? Give an example of each.

86. How do the sundew and the butterwort catch insects? What happens to the insects caught by them?

87. Write a description of mistletoe and dodder. Why is the eyebright called "milk thief"?

88. Give examples of some English saprophytes.

INDEX

GLASGOW: PRINTED AT THE UNIVERSITY PRESS BY ROBERT MACLEHOSE AND CO. LTD.

FIRST BOOKS OF SCIENCE

Globe 8vo. Price 1s. 9d. each.

A First Book of Arithmetic. By S. LISTER, B.Sc.

A First Book of Geometry. By J. V. H. COATES, B.Sc.

A First Book of Practical Mathematics. By T. S. USHERWOOD, B.Sc., and C. J. A. TRIMBLE, B.A.

A First Book of Physics. By L. LOWNDS, B.Sc. (Lond.), Ph.D.

A First Book of Experimental Science. Arranged by W. A. WHITTON, M.Sc. From *Lessons in Science* by Prof. R. A. Gregory and A. T. Simmons, B.Sc.

A First Book of Chemistry. By W. A. WHITTON, M.Sc. Science Master, Holloway County School, London.

A First Book of Botany. By ELIZABETH HEALEY Associate of the Royal College of Science, London.

A First Book of Nature Study. By E. STENHOUSE, B.Sc.

A First Book of Zoology. By T. H. BURLEND, M.A., B.Sc.

LONDON: MACMILLAN AND CO., LTD.

FIRST BOOKS OF SCIENCE

Globe 8vo. Price 1s. 9d. each.

A First Book of Physiology and Hygiene. By GERTRUDE D. CATHCART. M.B., B.Sc.

A First Book of School Gardening. By ALEX. LOGAN, Formerly of Gordon Schools, Huntly.

A First Book of Rural Science. By J. J. GREEN, B.Sc.

A First Book of Commercial Geography. By T. ALFORD SMITH, B.A., F.R.G.S., St. Dunstan's College, Catford, London.

A First Book of General Geography. By B. C. WALLIS, B.Sc., F.R.G.S.

A First Book of Physical Geography. By W. M. CAREY, M.A., B.Sc.

A First Geography of the British Isles. By W. M. CAREY, M.A.. B.Sc.

A First Book of Geology. By ALBERT WILMORE, D.Sc., Headmaster, Secondary School, Colne.

LONDON: MACMILLAN AND CO., LTD.